Tampereen yliopisto

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IMPROVING TRACEABILITY IN SPARE PART SERVICE

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ABSTRACT

Niilo Aho: Improving traceability in spare part service
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Traceability of products and services is a phenomenon which that has been popping out at discussion more frequently in last years, usually as a repercussion of global incidents. During the 21st century such examples can be found from food and pharmaceutical industry, as many others too. When considering the history of product traceability, the safety aspect can be identified as one of the main drivers for the whole concept of traceability. That is the main reason why the food industry has put so much effort in developing traceability systems in their industry, and why today they can be considered to be the forerunner of traceability. Technological development and increased customer awareness have also increased the interest to develop and implement traceability systems in other fields of business too. At the same time drivers to improve and develop traceability systems have diversified: traceability data enables them to develop and optimize business processes in the fields of quality, logistics, and efficiency just to mention a couple of examples. In addition to that, traceability also has been proven to be efficient way to increase sustainability development goals and circular economy on the supply chains. of examples. In addition to that, traceability also has been proven to be efficient way to increase sustainability development goals and circular economy on the supply chains.

At this work traceability will be studied together with spare parts, hence the target of this work is to develop the spare part process of the case company by developing the traceability of the spare parts. The focus is especially at the end of the spare parts lifecycle; how broken parts could be more recognizable and more traceable in the situation when time is of the essence and what different technological solutions could be used for that. The work has been commissioned by a global company that operates in the field of automation and indoor logistics. Within this project, the plan was to create a solid implementation plan and run the pilot testing at the main spare part warehouse of the case company, so that the concept could be put into practice in the whole organization later.

By comparing different technological solutions QR codes turned out to be most suitable for the case company. In enables to pass relevant information to customers in an efficient and cost-effective way. During the first phase of the project, QR codes will include data in text form, but in the future, they will also have a URL address. In the future the target is to find a web portal that can be used for sharing product and traceability-related data easily. All the technological solutions that were compared together were based on various sources, where they were proven to be effective solutions in different traceability applications. A Comparison was based on five main criteria which are discussed more closely in the text.

The main outcome of the work was three-phase implementation and development plan, which describes precisely how the case company could achieve the state of art traceability system in their organization. Contrary to the original project plan the system was not able to be done within the timeframe of this work. Therefore, execution of the presented implementation and development plan remains for the company itself, and it won't be reported at this work.

Keywords: spare part service, traceability, QR code, development project

TIIVISTELMÄ

Niilo Aho: Jäljitettävyyden kehittäminen varaosapalvelussa
Diplomityö
Tampereen yliopisto
Johtamisen ja tietotekniikan DI-tutkinto-ohjelma
Tarkastajat: Professori Marko Seppänen ja Yliopistonlehtori Rainer Breite
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Tuotteiden ja palveluiden seurattavuus on ilmiö, joka nousee säännöllisesti keskusteluun yleensä erilaisten kriisien seurauksena. Globaalilla tasolla esimerkkejä löytyy niin ruokateollisuuden kuin lääketeollisuuden puolelta. Historiallisesti tarkasteltuna juuri tuoteturvallisuus on ollut se tekijä, joka on toiminut seurattavuuden ja sen kehittämisen perustana, ja juuri tästä syystä elintarviketeollisuus on edelleen yksi alan edelläkävijöistä. 2000-luvun aikana tapahtunut teknologinen kehitys ja asiakkaiden valveutuneisuus ovat lisänneet kiinnostusta kehittää tuotteiden ja palveluiden seurattavuutta laajasti myös muilla aloilla. Samaan aikaan ne syyt, jonka vuoksi seurattavuusjärjestelmiä kehitetään ja otetaan käyttöön ovat monipuolistuneet: seurattavuusdatan avulla on mahdollista kehittää ja optimoida liiketoimintaa monialaisesti muun muassa laadun, logistiikan ja tehokkuuden osa-alueilla, jonka lisäksi seurattavuuden avulla on mahdollista edistää kestävän kehityksen ja kiertotalouden tavoitteita.

Tässä työssä seurattavuutta tarkastellaan ensisijaisesti varaosaprosessin kannalta, sillä työn tavoitteena on kehittää kohdeyrityksen varaosaprosessia parantamalla varaosien seurattavuutta ja tunnistettavuutta tuotteiden elinkaaren loppupäässä. Erityisesti huomioidaan tilanteet, joissa rikkoutunut osa pitää pystyä tunnistamaan ja korvaamaan nopeasti niin että järjestelmä saadaan mahdollisimman nopeasti takaisin tuotantokäyttöön. Työ toteutettiin projektiluontoisena globaalisti toimivan automaatioalan yrityksen kanssa, ja tavoitteena työssä oli luoda ja pilotoida konsepti, joka olisi mahdollista ottaa käyttöön organisaation kaikissa toimipisteissä.

Erilaisia teknisiä toteutusvaihtoehtoja vertailemalla kohdeyritykselle parhaaksi vaihtoehdoksi osoittautui QR-koodiin perustuva seurantajärjestelmä. Se mahdollistaisi tuotetietojen välittämisen asiakkaalle ensivaiheessa tekstimuodossa, ja tulevaisuudessa sen avulla olisi asiakas voitaisi tehokkaasti ohjata kohdeyrityksen Internet-sivulle, jota kautta teknisten tietojen jakaminen olisi helppoa. Vertailuun valikoituneet tekniset ratkaisut perustuivat lähdeaineistoihin, joiden kautta ne voitiin todeta yleisesti soveltuviksi tekniikoiksi seurannan toteuttamiseen. Vertailu toteutettiin viiden kriteerin pohjalta, jotka on tarkemmin esitelty tekstissä.

Työn tuloksena kohdeyritykselle luotiin kolmivaiheinen käyttöönotto- ja kehityssuunnitelma, jonka avulla yrityksen olisi mahdollista tulevaisuudessa toteuttaa kyseinen kehitysprojekti. Alkuperäisen tavoitteen mukaan työn puitteissa oli myös tarkoitus suorittaa järjestelmän pilotointi kohdeyrityksen keskusvaraosavarastolla, joka kuitenkin olosuhteiden pakosta jäi toteuttamatta. Työssä kuvataan käyttöönotto ja kehityssuunnitelman valmistumisprosessia, kohdeyrityksen tarpeiden määrittelyä sekä itse suunnitelman eri vaiheet. Lopullinen projektin toteutus jääkin yrityksen hoidettavaksi, eikä sitä raportoida tässä työssä.

Avainsanat: seurattavuus, varaosatoiminta, kehitys, QR-koodi.

ALKUSANAT

Noin puolen vuoden ajan alkusanat ovat olleet pelkästään tyhjä sivu; jotain, josta pitää huolehtia vasta kun kaikki muut osat tästä työstä ovat kunnossa. Yhtäkkiä se on kuitenkin ainoa osa tässä työssä, joka erottaa keskeneräisen työn valmiista. Maalin jo häämöttäessä haluaisinkin kiittää muutamia henkilöitä.

Ensinnäkin, suurin kiitos lopputyön osalta kuuluu Cimcorpille, ja erityisesti Heikki Seppälälle, jonka kautta työn toteuttaminen tuli mahdolliseksi. Lisäksi haluan kiittää professori Marko Seppästä ohjauksesta. Olen tyytyväinen, että työskentely teidän molempien kanssa oli helppoa ja sujuvaa, koen molempien vaikuttaneen omalta osaltaan lopputulokseen juuri sopivasti – kiitos käyttämästänne ajasta.

Viimeisimmäksi, muttei vähäisimmäksi, koko valmistumiseni kannalta tärkeäksi osaksi muodostui pieni, mutta tiivis ainejärjestöporukka, joka ansaitsee kiitoksen. Ilman yhteisiä pähkäilyitä ja ideointien sparrauksia monen kurssin lopputulos olisi ollut nykyistä heikompi.

Porissa, 23.10.2020

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1. INTRODUCTION

Traceability of the products has become an integral part of modern supply chains [1]. In addition, it affects the efficiency of the supply chain and how it can be managed, in some fields it is also strictly regulated and required by law. European Union has regulated the food industry by law since 2002, which sets clear requirements for traceability through the entire supply chain [2]. This type of legislation enables also transparency for the consumer, which has been seen as an essential feature in the European market.

Drivers for using and improving different traceability systems vary between companies and industries. Traceability might be used, for instance, for quality assurance, to gather information about the supply chain, to optimize the reverse logistics of the supply chain or to protects markets [3]. Nowadays consumers are also pressuring companies to provide more information about the sustainability of the products and the whole supply chain, which can be gathered through traceability systems. Green values and ecological consumption are no doubt big trends in the future, and traceability can be used as a tool to meet the market needs.

While drivers and technological aspects of the traceability may vary, after all, the main focus behind all actions should be on a customer: actions should be rationalized by increased customer value. As a customer value is created by different processes in different industries, some common elements can be found, for instance, quality, customer satisfaction, and lower price [4]. Traceability enables quality improvements by tracing quality errors in a supply chain, which reduces costs and increases customer satisfaction in the long run. Alfaro and Rábade came to the same conclusion and stated that traceability could be used as a tool for differentiation, and it can provide a competitive advantage for the company [5].

Hence, it’s quite clear that if traceability is managed well, it has positive internal and external effects for the organisations and its supply chain, depends on how widely this phenomenon is observed. But, as always, the implementation is strongly dependent on money. Despite the level traceability or technological aspects that are used in the supply chain, there are always costs related to it, and all the costs affect directly to the retail price of the product. This means that companies must find an equilibrium between costs and the level of traceability.

1.1 Previous studies

Traceability has been studied quite a lot in the fields of food, pharmaceutical, and military sciences [6,7], yet spare part business has not been discussed in studies barely at all [8]. While academic studies of spare part business have focused on elsewhere, traceability is an integral part of spare part management in many fields of business, and it is a popular topic on whitepapers of commercial actors. This indicates that the business potential of traceability has been recognized at the general level as a way to improve different processes in the company.

For decades the food industry has had a major effect on the concept of traceability, as it has developed global standards and technologies tracing goods. The same effect can be seen also in scholars: food sciences have studied traceability extensively from different angles [3–5,8,9]. After traceability became part of the ISO 9000 quality certificate in the 90's it has slowly become in wider knowledge in the manufacturing business, not just as a mandatory part of a certificate, but as an integral part of manufacturing processes.

[8] reviewed the traceability literature from the years 1990 – 2017, their findings also highlight the role of the food sciences in traceability studies. One trend that they identified was the increased number of purely technology orientated studies, i.e. focusing to implement Internet of Things (*IoT*) or blockchain-based traceability system [7,10,11], also, bioscience is a topic that interests continuously more. Both, IoT and blockchain, among few other technologies are described more closely in chapter 3. As the main focus of this thesis work is to discuss both technical and business aspects, some technologies are introduced in chapter 3.

Surprisingly one topic that has no mention at the study of [8] is sustainability. In recent years, increased numbers of studies have started to consider traceability as an effective way to improve the sustainability of the supply chains [12,13] and partly as an enabler of circular economy [14]. Researchers have even implemented the term *sustainable supply chain management* (SSCM) which itself is a clear signal that sustainability has an important role in today's business [12], but it also underlines the fact that companies can have an impact on their supply chains with active managerial decisions.

The principle behind the conclusion that links traceability and sustainability together in its simplicity is as follows: by using traceability data companies can verify the sustainability actions in their supply chains and precludes *greenwashing*. However, the idea is based on the assumption that either customers or the focal company at the supply chain require clear actions for sustainability. Therefore, despite the fact that [8] did not discuss the relationship of sustainability and traceability in their study, it is clear that it is one major topic of the future in the field of traceability.

1.2 Background of this work

Traceability – familiar term for most of the people which is usually associated with consumer goods and the ability to withdraw goods from markets. Yet it is something that must be considered at some level with every product or service that is produced; each company must keep record of where or to whom they have sold something. Traditionally traceability has been considered as matter/responsibility of manufacturer or vendor, but in the spare part business, the situation may not be as simple. Large manufacturing companies are highly dependable on their spare part stock so that they can maintain their high uptimes. When they recognize that a single part has too big a failure rate, they have to be able to trace that part back to its vendor or manufacturer. In order to be able to understand more the speciality of the spare part business, this section focuses on explaining the fundamentals of spare parts and the spare part supply chain.

Spare parts are common stock items, which are held in stock to reduce the downtime of machinery caused by planned maintenance or sudden brake down. In the field of manufacturing the spare part stock is playing important role in achieving the desired operating time at minimum costs. Customer value in the spare part business is twofold; it is created from physical products and services, such as the availability of those products [15]. It is estimated that spare parts and maintenance services form a lion share of life cycle costs of industrial machinery. According to [16] normal manufacturing machinery consumes spare parts annually amounting to as much as 2,5 percent of the purchase price. In the manufacturing industry where acquisition costs can be millions or tens of millions, and the lifespan of machinery up to twenty years, it is clear that companies spend a substantial amount of money on spares every year.

The discussion about the total price of spare parts revels the main dilemma behind whole spare part management: what is the optimal level of preparation (stock levels), shutting down the production is always very expensive, but so is keeping the huge stock. By finding the optimal level of spare part stock, company will save money and maintains its competitive advantage. The optimization of spare part stock is a topic that has been researched a lot, and academic research it can be considered as its own subfield of warehouse management. Even this fundamental challenge of spare part stocking is not directly linked to the topic of this work it is something that needs to be taken into account always when operating with spare parts.

Today providing spare parts to customers can be considered as the most prominent after-sales activity for the manufacturing companies. It has a major effect on customer satisfaction in the context of the life cycle of industrial products. While the supply chain has been discussed briefly in the previous sections, the spare part supply chain is also a thing that should be discussed more closely, hence it has some special characteristics compared to the regular supply chain. By its structure spare part supply chain is just like any other supply chain, what makes it different it has to fulfill customer's needs much faster.

MoosaVirad describes the spare part supply chain in his paper *Knowledge Management among Spare Parts Supply Chain Partners* (2013) by identifying its specific characteristics as follows: [17]

- Spare part stockouts may cause great production lost
- Managing and procuring spare part inventories requires capital
- Demand patterns may be non-symmetrical
- Part failures are often dependent on various activities. This becomes a problem when dependence relations are not known.
- Demand for a urgent spare part may be fulfilled through cannibalism of other parts
- Material and time buffers in manufacturing systems and supply chains are decreasing
- The function of spare part inventory differs greatly from product inventory. Spare part inventory is held so maintenance staff can keep production equipment in operating condition.

[18] also brings out the time dimension which is much more critical in spare part supply chains, because demand may be caused by a mechanical failure or another surprising event. Hence the majority of spare parts have relatively low or no-demand at most of the time [18], it is clear that it causes great challenges in the matter of inventory management and forecasting the demand. With modern algorithms and artificial intelligence (*AI*) applications, forecasting can be done, but the outcome is highly dependent on the quality of the available data.

Described sudden demand peaks for spare parts is the main reason why time is considered to be the most valuable resource in the spare part supply chains. Whether the production unit is large or small, already small decrease of the production capacity may cause big financial losses, and lost production is a resource that can’t be restored. [18]discuss this problem too: critical spare part should be able to keep in inventory, to minimize the risk of production lost in the case of part failure, yet it’s not economically reasonable to stock all different spare part, only the critical ones. Their solution to this problem is efficient the spare part supply chain, which should be developed and coordinated jointly [18].

Traceability of spare parts can be considered as one way to improve the efficiency and flexibility of the spare part supply chain. Despite the concrete implantation (internal or chain traceability, or what kind of technological solution is used), traceability can make the process of identifying the broken part and identifying the supplier of that part much easier.

1.3 Research questions

For the organizations that operates all around the world, traceability is extremely important on many levels. Generally, it can be divided into internal and chain traceability; internal traceability focuses on keeping a record of all the operations that a specific part or product goes throughinside the company, and external traceability focuses more on actions made on the supply chain level such as movement between different actors [19].

Even traceability and spare part management have been both studied extensively, there are not too many studies that discuss both topics and how they are influencing each other. Therefore, it was rather interesting to look into both topics and see how they could be combined in a reasonable way, and so that it could be implemented into action too. The decision was made to operate with two main research questions which are:

- What is traceability in the spare part business
- What techniques can be used to implement traceability into case company

As said, spare part business and traceability are topics that scholar have not discussed together too much, there are some studies which discusses the traceability of the spare parts, but the mainly from the technical point of view. Therefore, the target of this work is to first explore the field of traceability at a general level, what it means, how it can be used, what are the most common challenges with it, and combine it with combine it with the principles of spare part management. As a result, the target is to form an idea or a synthesis of how traceability could be used in the spare part business.

While the first research question is discussed purely on a theoretical level, the second research question tries to find the most optimal solution for the case company – Cimcorp

Ltd. This question was important to limit to handle only one company, hence all technologies that will be introduced are used in different traceability systems, but the differences can be found from their suitability for different situations. The target is to find the best solution by comparing suitability of different solutions at the working environment of Cimcorp.

1.4 Structure of the work

This work is divided into five chapters. The first chapter acts as an introduction to this thesis work by describing a little bit of the background of the traceability and why traceability should be considered important. For the same reason the introduction includes a brief section about previous studies related to traceability, they help to understand the current state of traceability studies. The basic concept of spare parts is also introduced together with the spare part supply chain hence they have an important, yet indirect role in this work.

The second chapter focuses on presenting the theoretical background of traceability, ERP systems, and customer satisfaction and defines them by exploiting academic literature. The chapter discusses the challenges and opportunities that can be achieved by implementing a traceability system in action. ERP systems are also discussed at general level since they form the core of the company IT architecture, and thereby it has strong linkage to traceability systems too. At the end of chapter 2, there is a summary that pieces the topics together.

Chapter three then introduces different technical solutions for implementation on a practical level. Solutions are divided into two main categories: technology-based and system-based. Technology-based solutions are single technologies that can be utilized for traceability systems. System-based solutions on the other hand are more upper-level solutions, which can include various technologies cotemporally. Hence, one objective in this work was to find an optimal solution for Cimcorp and improve traceability in their spare part business, different solutions are compared against five indicators. Those indicators, or comparison framework, are introduced at the beginning of the chapter.

Then, chapter 4 focuses on actual implementation planning and actual implementation. The chapter starts with an introduction of the case company and the organizational structure where the planned traceability system will operate in the future. The planning process describes why and how certain decisions were made, what limitations there were that needed to be taken into account, and finally the outcome of the planning; three phase implementation and development plan for Cimcorp to increase traceability in their spare part services.

2. TRACEABILITY INCREASES CUSTOMER VALUE

The need for tracing the goods through the supply chain is not a new thing: it has been popping up more often in discussions about safety and transparency of the supply chains in the last years [20]. Drug, food, and military industries, for instance, have intensely develop their traceability systems for decades already [7]. Development of technological capabilities, the internet and globalisation has increased the pressure for other businesses too to improve traceability, hence it has proven to be efficient way to improve operational effectiveness and sustainability [21].

In the industries that were mentioned above, the most important reasons for tracing are usually safety-related concerns. In a case of accident or emergency, it is crucial to be able to track down the whole batch and withdraw it from the markets or customers if it's possible. The quality perspective is also strongly presented at the studies related to those industries [4,22]. Product safety and quality control are linked together, and both are required to meet the high expectations of the customers.

During the last decades, global supply chains have developed from streamlined chains to complex supply networks. At the same time requirements for traceability and transparency have changed dramatically; before those features could be used to differentiate from competitors, but nowadays they can be considered as mandatory features to achieve high customer satisfaction, and sometimes to meet requirements written in law.

In order to be able to implement traceability in a complex supply network, a collaboration between all operators in the supply chain at some level is essential [23]. Global standardisation organization GS1 recognises the need for close collaboration but also underlines the role of efficient information flow, which they see as a fundamental key to a successful traceability system [24]. The level of collaboration between different actors through the supply chain is highly dependent on how widely traceability is implemented, this question is discussed more in chapters 2.1 (internal and external traceability) and 2.4.

2.1 Defining traceability

ISO 9000 standard defines traceability as an ability to follow up the history, application, and location of an object. Whether the object is considered as a product or service, traceability data should include the origin of the materials, processing history, or location after the distribution [25]. Even this definition is relatively loose it may be the most used one hence the ISO 9000 quality standard is so popular. The thing that is worth noticing in this definition, is that it does not take into account the supply chain in any way.

GS1 is another global organization that maintains and develops its own standards related to the product data and identification [24]. One of GS1's best-known standards is EAN-barcodes that are widely used in the retail business. While the organization uses its own definition for the traceability, they also bring up the ISO 9000:2015 definition. Hence, the GS1 standard can be seen as a supplementary standard for specific business areas.

GS1 considers the traceability in a matter of whole supply chain/network, and it includes all the activities through the lifecycle of the product or service. The listing underneath classifies all the actions that GS1 considers to be included in the concept of traceability [24].

- Processing the raw material and ingredients
- Aggregation and disaggregation of the products
- All kind of transportation
- The maintenance or repair operations related to the product or service
- Consumption of the product
- Disposal, destruction, or recycling of the product or materials

In academic literature, there are no unambiguous definitions for traceability even it has been discussed in scholars' decades already. One reason for that may be found from how non-profit organizations (i.e. GS1 and ISO) have had a big role on developing the whole concept of traceability: their interests have been to develop a system (and definition) that serves commercial actors. While the conceptual idea behind all definitions is quite much the same, different studies emphasise different perspectives. Skilton and Robinson define traceability as an ability to identify and verify the chronology of the products of the actions that have been made in the process chain [23]. Their idea and definition differ from other definitions by underling the chronology of the recorded traceability data.

Olsen and Borit definition emphasise the lifecycle of the product so that all the actions that are made during the product lifecycle should be traceable [9]. It is easy to see why this definition is used in the food industry where customer safety is a major concern in all actions, but in many other industries tracing the products through the whole lifecycle isn't realistic hence end-to-end traceability requires vast collaboration and usually its own organization. Karlsen, Olsen, and Donnelly stated in their study that traceability should not been seen just as a product or process information, but as a tool, that makes it possible to retrieve all the relevant information in a later date [26]. It is surprising that no other basic study papers in the field of traceability have not considered traceability as a tool that can be used to accomplish different objectives. The described tool analogy would have the potential to be adapted for wider usage, since it has a broad scope of affordance, yet it does not set any restrictions on how traceability should be executed. It also underlines how traceability should not be seen as intrinsic value, but more as a system that enables to manage produced products more efficiently throughthe product lifecycle.

In general, different definitions can be categorized into two types: the ones that consider the traceability as a matter of the whole supply chain, and the ones that see it just from one company's perspective (chain traceability and internal traceability). At figure 1 is shown the process of internal traceability. Even if it's a quite simplified figure, it reflects the basic concept; the company records all the actions that are made inside the organization and collected data that is available only internally. Almost all companies have some processes that produce data that would be used in an internal traceability system, even if they might not utilize it in any way. Internal traceability data can include information on the movements of physical products or information about who has worked with the product in question. According to Thakur and Donnelly (2010), functional internal traceability system can be considered as a mandatory if the company is pursuing to develop/implement a chain traceability system [27].

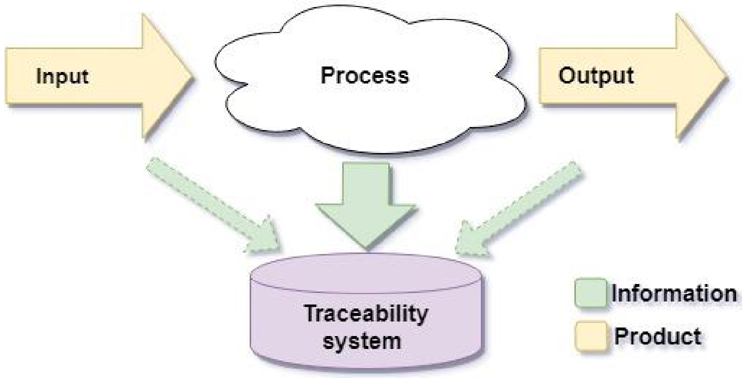

Figure 1 Concept of internal traceability

For many companies internal traceability is part of a normal business process, where all data is collected to the ERP system, this data is then used, for example, to manage product warranties. The data may not be considered as traceability data and most of all, this data is not used proactively. It is important to remember, that for many companies described reactive usage of traceability data is an adequate way to operate.

However, there are situations when internal traceability will not be enough, and information is required from outside of the own organisation too – then the solution is a chain traceability system. Figure 2 illustrates the concept of the chain traceability and shows how it differs from internal traceability.

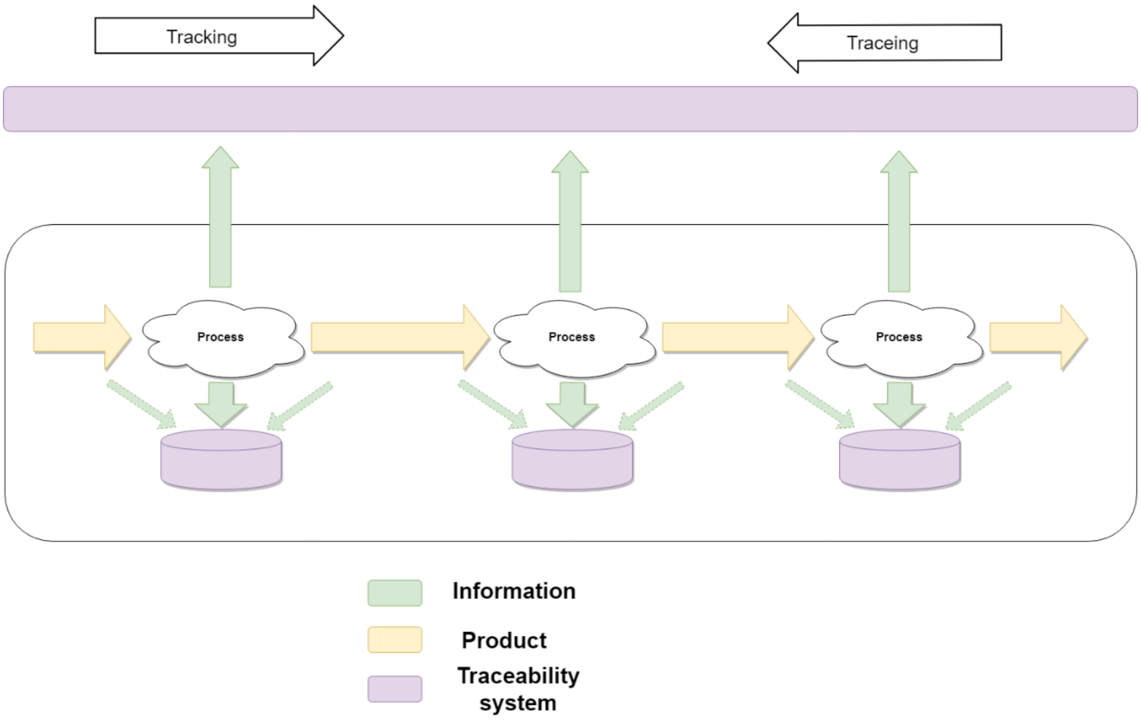

Figure 2 Chain traceability (modified from* [4]*)

As can be seen, it is a much wider entity than internal traceability, which means it requires much more collaboration between companies and resources to be invested. For small and medium-sized companies the costs of chain traceability systems can easily get too high. Still, there are also distinct advantages that it can provide: end-to-end supply chain data may be used, for instance, to optimize logistics operations, improve product safety, or to analyze the risks trough the supply chain [28].

The food industry can be said to be the first frontier of the chain traceability, partly due to legislation, but also due to their will to increase the customer value. As an outcome of this development work, they have founded non-profit organizations, such as GS1, whose mission is to develop, standardize, and share the best practicesof the industry. These organizations that are based on collaboration are also one reason why food industry has succeeded to implement chain traceability systems effectively also on a global scale.

In addition to internal and chain traceability, some studies have also introduced terms backward traceability, forward traceability, and tracking. They are more detailed adjustments that can be used to describe actions in the context of chain traceability. Forward traceability is used to describe a situation where tracing is needed for upstream of the supply chain. Sometimes forward traceability and tracking are also used as a synonym for each other. Product recalls are one example of why the ability to do forward traceability is important; based on some estimations, recalls may even be the most significant application of traceability [29]. Backward traceability on the other hand focuses on tracing all the processes and actions that have been before the focal company. [22,30]

2.2 Demands of the business

Whether the company decides to implement the internal or chain traceability, there are several benefits, but also challenges, that can be accomplished in day-to-day operations and in strategical level. Although in practical level pretty words and theoretical benefits are usually not sufficient drivers for development projects, mostly they are driven by a specific need or demand, i.e. demand to increase operational effectiveness. This section will be discussing how different business demands can be solved or at least affected by traceability.

High quality

Correlation between quality management and traceability is strong and widely recognized [19]. “*What you can’t measure, you can’t manage*” is much-used expression, which in its all simplicity contains the core of quality management. Quality management and quality improvements are extremely reliant on the ability to measure ongoing operation and process as precisely as possible. Hence traceability system can provide solid data from the products and their movements internally or at the supply chain, traceability can be said to be fixedly linked to quality management and quality management systems. This link is highlighted especially on business-to-consumer markets where massive withdraw campaigns happen occasionally, not often but still regularly. Modern quality management systems notice this linkage already distinctly, such as the ISO 9000 standard, which obligates organization to identify the product and its components by “*suitable means*”. Some scholars have interpreted that the idea of traceability can be found from older quality tools also, not as distinctly, but at some level at least.

Deming’s PDCA-cycle and JIT (*Just-in-Tim*) are already a bit old, but still much-used quality management tools in many industries. According to Aung and Chang (2014), traceability has linkage to both, even originally, they did not use the term traceability, but the idea was the same; continuous improvement, which is the foundation of both tools, is dependent on accurate and available data, including production data, product data, etc. Aung and Chang point out that the need for traceability data has existed already for a long time it has not been perceived that way. They also underline how traceability data also has a great indirect effect on customer confidence and satisfaction, which are caused by the ability to make better managerial decisions and increased quality of the products [4].

Another quality management tool that can be linked to traceability is root-cause analysis. According to Kendrick (1994, cited by Töyrälä, I., 1999), traceability data can also be used effectively for root-cause analysis in the supply chain level. While there are a lot of examples of how the food industry has used root-cause defect identification in their supply chains, it can and should be used in other fields of manufacturing too, although not many industries are capable of it yet. The technology industry, and more specifically companies that work on consumer electronics, is a good example of how well their traceability systems can operate these days: during the protest the US in 2020 several Apple stores faced burglaries and hundreds of iPhones were stolen. However, thanks to the traceability system, which was based on MAC-addresses, they were able to trace each device.

Another point that Töyrälä emphasises is that traceability data can be used also as a proof-of-quality or quality-of-origin. This kind of information is becoming more popular among stakeholders, while end customers can be sure that the quality meets their needs, and upstream operators in the supply chain can be, for example, assured that environmental issues have been dealt properly. Traceability as a proof-of-origin is much used in the drug industry, where counterfeit medicines are big problem on a global level. [29]

In the spare part business relation between quality and traceability is also strong, it can be even described as fixed, since quality problems appears usually by break downs of machinery, which then requires the participation of spare part function. Yet a quite common and unfortunate situation with the spare parts is that when they are needed, the time is of the essence hence lost production time cannot be restored. By implementing traceability system all relevant data related to the product, product movement, and end-customer is easily available, which speeds up the whole spare part providing process and helps normalize the customer's manufacturing process faster.

Improving logistics operation

In logistics management chain traceability is one way to achieve the more efficient supply chain by enabling the information to flow both ways at the supply chain. Collaboration between different actors allows, for instance, reverse logistics, deeper tier risk management, on-time delivery performance, and logistics optimization [19,31].

[28] have studied supply chains and how traceability affects them, and they stated that from the logistic point of view traceability and visibility should be handled together. They founded that improving the traceability at the supply chain visibility increased distinctly, and visibility for one provides a better platform to create logistic partnerships thought the supply chain. And a close relationship with business associates offers a are key to better operational flexibility to react to the changing needs of the markets. In a modern continuously changing markets long-term partnerships are extremely valuable; hence they can offer a competitive advantage that is hard or even impossible to imitate. Based on the findings of Florence at al. it can be concluded that traceability is one connection in a larger chain, which can have a major positive effect on the company. Findings of Resende-Filho and Buhr (2008) supports this conclusion too; they find that traceability reduces information asymmetry quite effectively in the supply chain, which improves the allocation of economic value [32].

Now when it can be assured, at least in some level, that traceability can have positive effect on logistics, in the context of this work, the most interesting question is how it effects on logistics of the spare part operation. The demand for spare parts has always some fluctuation and volatilization, which complicates the after-sales process [33]; stocking spares requires large amounts of space and money, furthermore, the demand for spares can be extremely hard to forecast. Customers expect quality customer service and fast deliveries every time, which may cause pressure for the company’s logistic operation. Traceability itself will not solve the root problem, the uncertainty of the demand, but it enables to react to customer’s needs faster.

As said, traceability is a tool, but still, one tool that can be used to decrease the pressure of logistics in spare part business. By optimizing the logistical process companies can deliver their products much faster and more efficiently to customers, which has a partial effect on customer satisfaction. Practically the challenge with logistics optimization today is that few companies run their own logistics operation anymore, which means that companies have only limited chances to affect outsourced operations.

Logistics also plays a major role in the environmental sustainability of the supply chains. In the past, most of the companies had to decide whether to maximize the profit of the company or to run an environmentally sustainable operation. Luckily the trend in the modern supply chain is totally different and environmental sustainability goals are valued by customers and other stakeholders. Examples from reverse logistics or general logistics optimization have proven that companies can operate sustainably and still succeed financially. [13]

Traceability as a competitive advantage

Alfaro and Rábade stated in their paper, that traceability can be used as a way to differ at the market, which can be used as a source of competitive advantage in the long run [5]. The essence of competitive advantage is similar to customer value; it is not tangible and dynamic by its nature. The dynamicity of the competitive advantage is a consequence of the changing needs of the markets where all the companies pursue to gain bigger market share by bringing up new innovations.

While discussing the dynamicity of the competitive advantage, is important to highlight, that automatically it is not a good or bad thing for the company. There are two sides on a one coin; once achieved competitive advantage isn’t permanent, the company must closely follow the changing needs of the markets and develop their product and services to maintain a good position at the markets. Yet, if the company gains competitive advantage from intangible assets, it can be really hard to imitate by competitors. This kind of competitive advantage, which is based on well-managed processes and knowledge is always much hard to imitate. So, if a company gains a competitive advantage from intangible assets, small changes in the markets may not have effect on in.

Michael Porter has stated that competitive advantage is created fundamentally by the value that a company is able to create for its customers [34]. By producing products or services companies offers solutions to customers current as well as their latent or future needs. This means that companies must work continuously towards competitive advantage, even if it may not be clear what is the best way to achieve it.

In the context of traceability competitive advantage should be considered more as a sum of different actions and improvements rather than the cause of single action. In the spare part business, which is mainly B2B sales, competitive advantage is highly dependent on how well the customers’ needs can be fulfilled. Well managed traceability system makes reacting to customers’ needs easier and lowers the threshold for contacting between supplier and customer.

Operational effectiveness

So far traceability has been discussed mainly from the process point of view; how the implementation of the traceability system could affect quality, logistics, customer value or competitive advantage. These actions can be yet divided into two categories, features, which are tangible; quality and logistics, and the ones that are an intangible competitive advantage. While discussing the traceability in operations level it is worth noticing that in operations management it is considered as the most abstract level of the taxonomy with the broadest point of view; operational effectiveness is concern about all activities related to operations.

Generally, operations are defined to cover all the business activities that the company does to transfer raw materials (*inputs)* into finished goods or services (*outputs*), including intangible resources like knowledge and professional capabilities.

While traceability has great potential to improve, for instance, quality of the products or services, and improve logistic operations, there is also a bigger scale context that interests all operations managers – operational effectiveness. Traditionally uncertainty and complexity of the operations have been considered as the biggest threats to operational effectiveness, since anticipating uncertainty and complexity requires inventories and a lot of time for management actions. There are indications, that the traceability system can be used effectively to tackle uncertainty and complexity across global manufacturing systems [23]. Resende-Filho & Buhr also ended up to a similar conclusion, but with different arguments; they found that (chain) traceability can reduce information asymmetry in the supply chain, resulting in improved allocation of economic value [32], , which has great effect on operational effectiveness too.

Michael Porter stated in his paper (1996) that operational effectiveness should not be seen as a strategy, but as a necessity on the road of global success [35]. He points out that operational effectiveness is almost like a by-product of in-house activities that have been performed better than rivals, which in the long run leads to competitive advantage too. Therefore, the old saying may be right; "Efficiency is doing things right, but effectiveness is doing the right things".

Another operation level phenomenon that is affected by traceability is supply chains; how they are managed, how they can be optimized to be more efficient, etc. It has already been demonstrated on how the supply chain and traceability are linked together in practice. While discussing supply chains and how traceability affects them, it is important to understand the role of the supply chains for the success of the companies.

It is said, that in a global market individual companies cannot achieve sustainable competitive advantage singlehandedly anymore, but integrated supply chains are key to global success [36]. Reason for this may be found from technological development; most of all, integration involves communication between all the members, chain traceability system is one tool that allows information flow through the supply chain. So again, together with other tools traceability has great potential indirectly to affect operational effectiveness positively.

2.3 Challenges of implementation

Based on the previous section it is justified to say, that traceability has great potential to affect positively on the company's operation. But, as always, there are also challenges and things that need careful consideration so that organizations can find the most suitable practicesfor them. As mentioned already, traceability shouldn't be considered as an intrinsic value, but more as a tool which increases the customer value if it is managed properly. That is something that should keep in mind, especially with particularly technical solutions.

One of the main challenges that lies between traceability and implementation of a traceability system, is how it can be fitted into an existing organization effectively. Scholars have used contingency theory to describe the challenge with traceability implementation [20,23]. The theoretical framework of contingency theory is a useful tool that helps to understand the environment or the "playground" which effects on the background to problem solving.

Contingency theory is an organizational theory which describes on how there is no single "right" way to organize the company *(i.e. structure, decision processes, hierarchy*) as it is always dependent on several factors, such as business environment, technology, employees, etc. In the context of traceability, contingency theory can be used to explain how a company can improve its strategic competitiveness by implementing a contingency response on a demand from internal and external stakeholders. [20] Thoughts of the Barratt and Choi follows the same trail; they stated that implementation of the traceability can help a firm to create unique resources that differentiate it from the competitors and are hard to imitate. Yet, to achieve that competitive advantage traceability systems and policies must be tailored to the system they are deployed in. [37] The main challenge is that since every company is individual and every implementation project is too, there are no answers on how traceability should be implemented so that all benefits could be achieved.

Another challenge that companies may face while implementing the traceability system is the complexity of the supply network. From a point of operations management research view, supply chains and supply networks are nowadays considered as complex systems, which involves a different type of participants exchanging products, services, and information [23]. While the complexity of the supply network increases, increases also the possible benefits of the traceability system, hence an advanced traceability system can provide accurate data to improve managerial decisions. Yet Skilton and Robinson (2009) founded that traceability and transparency will most likely decrease while the complexity increases.

While Skilton's and Robinson's results may indicate great challenges for larger organizations, they do not judge traceability as a lost call, even in complex supply networks, they just underline the necessity of tailored solutions [23]. In addition, in complex systems accessibility of all kinds of information becomes also vital. Martin's (1993, cited by Töyrälä, T., 1999) idea, that if the information is not easy to access, it probably will not be used either, is also relevant while discussing the management of complex supply networks. One interpretation from that could be, that to be effective traceability system must have high usability, at least in theory.

In a business environment, one thing that affects every decision at some level is money. On a theoretical level traceability has various benefits for the focal company, and for whole the supply network, but in practise it has been turned out that described systems can have significant investment and operating costs. Töyrälä points out, that the traceability system should be evaluated as any other investment in a company; by comparison between costs and benefits even it may not be easy [29].

A rather interesting result was presented in [38] study, where they studied critical points of traceability implementation in the food industry. They found that motivation was the biggest single matter that affected the success of the implementation, neither technological solutions nor money. The relationship between motivation and management was also underlined; if workers from all levels are not committed the success rate decreases dramatically. In line with that, [20] also have stated that the support from management is crucial to the implementation of traceability systems. According to them, contingency theory explains, that from the top of the organization managers detect demands from stakeholders for traceability initiatives. Both studies also shared the conclusion, that managers have a major role identifying the tangible benefits of traceability, which directly affects the motivation of the workers.

As a conclusion, it can be said that every company has to face some or all of these described challenges during the implementation. Individual contingency factors, the complexity of the operations and processes and “lack” of money can be all described as critical factors while considering a single organization. But if this phenomenon is observed in the bigger picture management of *soft resources* is actually much more critical:

complexity and money can be overcome with proper resource allocation, but managing employees is the real challenge.

2.4 Level of traceability

In order to benefit from traceability as much as possible company must carefully determine what are their requirements and goals for implementing traceability overall, and then try to find a balance between pros and cons – costs and benefits [39]. One of the first things that must be considered during the implementation process is what the reasonable level of traceability is. When the unit price is low, item-level traceability usually is not realistic, hence low unit price products are usually bulk products: the amount of gathered data would be too large and especially too detailed to be handled. Higher unit price makes item-level tracking more reasonable from the point of customer and producer, it also enables to use more developed (and pricey) technologies for tracing, such as active RFID-tags. [40]

The scholars of the food industry have defined the term traceable resource unit (TRU) which is used locally as a basic unit of traced goods [41]. It is always related to its environment, whether tracing is done for manufacturing units, logistics units, or trading units, the idea is that company determines their own traceable resource unit aka the level of traceability [19]. If the traceability system is implemented trough the supply chain decision of traceability level must be done together with all operators. Thakur and Donnelly (2010) underline that the term traceable resource units do not have intrinsic value itself, the target is to standardize the units that are used to capture relevant and identifiable data so that it can be utilized whenever needed [27].

In spare part business, the question about traceable resource unit is relevant but also relatively complex. At the same time, there can be big and expensive parts as well as small and cheap ones in the stock, therefore the question is; which parts should be traced at item-level and which not, is it even reasonable to use more than one TRU's. There are some studies that briefly discuss this problem by using the term *granularity*, yet so far there are not even conceptual frameworks that could be used to solve it [42]. However, this does not mean that this kind of knowledge does not exist, it just has not been studied academically. Since traceability has been studied by commercial actors the knowledge is centered upon those companies.

2.5 ERP – Backbone of the traceability system

ERPs' are integrated software that are used to manage a firm's business and manufacturing processes in real-time via different technological solutions. [43] have described ERP as a system that can integrate information and information-processes across all the functions within the organization. In many ways companies are dependent on their ERPs' in managing and connecting day-to-day activities that are physically separated from each other, and it can be said that for many companies, ERP forms the backbone of their information system [44].

In general, requirements for ERP systems are quite extensive hence they must provide enough information to support top management's strategical decision-making and the same time extremely detailed information, for instance, about financials or capacity planning. This sets some challenges to ERP systems, and it may be also the reason why ERPs' are commonly considered as troublesome to operate effectively.

To ease the problem described above, ERP systems are designed into a modular structure which means that different functionalities have been separated into their own "blocks" [45]. Each functional block can be used, with certain constraints, individually or as a part of a larger system. The most common ERP modules are presented below [46]:

- Financial Accounting
- Management Accounting
- Human Resources
- Project Management
- Manufacturing
- Order Processing
- Customer Relationship Management
- Supply Chain Management

Although modularity makes it easier to provide tailored ERP solutions for the customers the standard procedure is that each module is yet tailored to match a specific requirement of an enterprise [45]. This kind of customizing requires usually a lot of manual work and time to get familiar with firms' business processes. Even it may take quite a much time, it is extremely important to model the real-world business processes carefully. If customized ERP doesn't reflect the real-world situation as precisely as possible it can cause inaccuracy in the decision-making process and in worst-case scenario discredits the whole ERP system inside a company [46].

Best practis is a term that is closely related to customization of the ERP systems. In the history of ERP system development, supplier companies like SAP, IFS, or Oracle have adopted the best and most efficient processes which have proved to produce superior results, and those are called best practices [46]. All the ERP systems are built around these best practices, and at the implementation phase companies can choose the ones that fit best for them. It also raises an important question; should companies put great effort into customizing ERP systems to fit their needs, or should they develop their processes to fit best practice (also known as *business process re-engineering, BPR*).

Velcu (2007) describes in her study how business process re-engineering can be considered as one of the key factor in maximizing the benefits of ERP system [47]. She emphasises the significance and opportunities of best practices, but at the same time raises up an interesting observation; most of the company's processes, even the core business processes are not that unique that they could not be re-engineered.

One fundamental challenge with ERPs' is that while they have huge potential to boost efficiency and profitability of the company, but there is also huge risk related to the implantation of ERP. It is estimated that even 50% of the companies fail to fully implement their ERP systems [43], which reflects the challenging nature of ERPs'. Even if challenges and risks related to ERP implementation are generally well recognized, the "failure" rate of ERP implementations has not decreased over the years. This trend can be considered slightly odd, since increased knowledge, in an academic and practical level, should have decreased the number of failures. One reason for this might be founded from the challenges that were described in section 2.3, increased complexity of the business environment and business processes makes ERP implementation continuously harder. Velcu has identified the benefits that are related to ERP systems and especially to the implementation. She classified four main categories that gained the biggest benefits, they were business process changes, internal efficiency benefits, customer benefits, and financial benefits.

As mentioned already, the linkage between the ERP system and traceability is fundamental, at least in practice. ERP is the main software and tool, which enables traceability information to flow, and it is also the system that connects company in-house processes to different shareholders. Yet, studies from the food industry have shown, that the requirements for traceability systems vary quite a lot between industries, and most of all, the ERP system will not provide enough support for them in the term of traceability [48].

As the academic literature lacks the knowledge about spare part traceability and ERPs, it can be assumed that the same conclusion is relevant in the context of this work too. This may also be one reason why there is a specified software for tracing goods through the supply chain.

2.6 Customer Satisfaction

Customer satisfaction is one of the key concepts in modern marketing, which describes delivering satisfaction to a customer and obtaining profits in return for transaction [49]. In many organizations customer satisfaction has become one of the most important key performance indicators (*KPI*), which are used in decision making at every organizational level. The role of customer satisfaction as a KPI indicates also that companies consider customer satisfaction strategically important measure to remain their competitive status at the markets. Traditionally theoretical background of customer satisfaction is based on the expectancy disconfirmation model, which compares customer's expectations to the perceived performance [49].

The expectancy disconfirmation model is after all relatively simple to understand; the customer is satisfied if the product or service is able to meet the expectations. If it considerably exceeds the expectations the customer will be very satisfied, and probably he/she expects the same experience in the future, so the expectations rise, if the performance remains below expectations the customer will be dissatisfied. Figure 3 presents the simplified concept of the expectancy disconfirmation model [50].

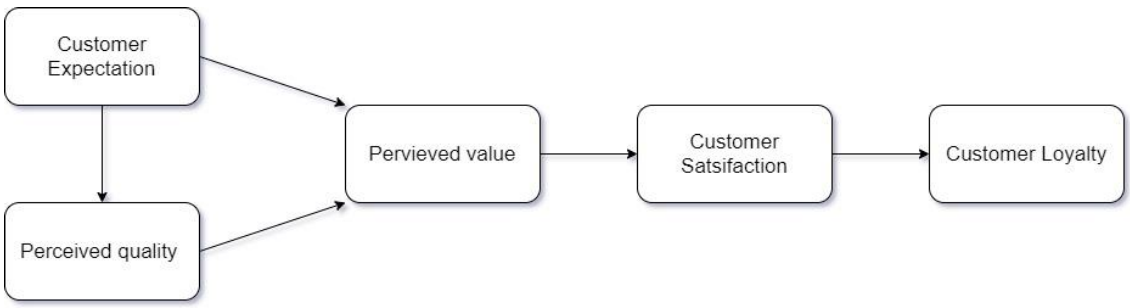

Figure 3 Conceptualization of the customer satisfaction model (modified from [50])

Although the scholars share a consensus on the foundation of the expectancy disconfirmation model, Eggert and Ulaga claim that the essence of customer satisfaction remains unambiguous [51]. They present that some satisfaction scales tap on the cognitive dimension and other capture its affective nature. The cognitive dimension could be described as a "rational" way, where customer compares the current experience on some standard.

Even though the deepest essence of customer satisfaction may be debatable, customer satisfaction and its effects on the business have been studied a lot. Scholars have linked customer satisfaction, for instance, to future cash flow [52], shareholders value [52], customer loyalty [53], and elasticity of the retail prices [54]. These are just few examples from a large field of studies, but it emphasises the role of customer satisfaction for, whole company and its operation.

Gruca and Rego studied customer satisfaction in North America and found that customer satisfaction has a significant effect on a company's cash flow in the short-term, which in turn reduced the variance in cash flow [52]. It can be said, that the result of Gruca and Rego is expected, but it is important to recognize that increased cash flow and decreased cash flow volatility are closely followed by a company's shareholders, hence they are used as metrics of sustainable growth in a company. It also underlines the importance of customer satisfaction for day-to-day operations.

Similar findings were done by O'Sullivan and McCallig, who studied how firm value and earning are affected by customer satisfaction. As a result, they found that increased customer satisfaction positively effects the firm's value, and also moderates the earnings – firm value relationship. According to them the relationship between customer satisfaction and earning, and their effect on firms' value is a valuable finding, hence it can provide relevant information to financial managers about the effectiveness of marketing activities. It also underlines the relevancy of customer satisfaction as a metric, and therefore it should be used as a KPI. [54]

Suchánek and Králová describe the effects of customer satisfaction on a larger scale on their paper *Affects of Customer Satisfaction on Company Performance* (2015). They found that there are several factors related to customer satisfaction that have an influence on a company's performance, but not individually, more as a combination. The five most affecting factors are presented below [55]:

- Experience with product
- Frequency of purchase
- Quality (in term of design and craftmanship)
- Price
- Customer shopping behavior

A rather interesting observation from Suchánek and Králová was that from those five factors, a company can directly affect only two factors; price and quality. As it has been presented in section 2.2, quality at least can be improved by implementing a traceability system. The other three factors are heavily dependent on customers' personal capabilities (i.e. money), hence, their conclusion was that these five factors have a relatively small effect on the company's operation after all.

While discussing customer satisfaction, it is important to notice that B2B and business-to-consumer (B2C) environments differ from each other significantly in many cases because consumers and businesses tend to act quite differently. Customer satisfaction is one feature that has a lot more value in B2B than B2C as an individual feature. It is important to underline that customer satisfaction is still relevant also in the B2C environment too, but there are some features that are normally considered to have a bigger affect on the final decision, for example, price and availability [56]. Loyalty is another feature that can be identified more common in B2B relations. But it is not just customer loyalty, it should be understood as mutual respect for the business relationship.

Customer satisfaction has been in a centre of marketing research quite a long, yet there is not much research that combines spare part management and customer satisfaction. Instead, some studies have discussed the relationship between after-sales actions and customer satisfaction, which may be the closest topic related to spare parts, after all, spare parts management usually is considered to be part of after-sales.

2.7 Summary

The object of this chapter was to introduce and examine the concept of traceability as it has been presented in academic research. Based on the presented sources there are couple conclusions that can be made: For a long time, traceability has been an interest of a relatively small area of businesses, mainly because traceability has been perceived solely as a product safety matter. This has led to a situation where commercial actors have had a greater interest in the topic than academics, which can be seen, for example, from the fact there is no unambiguous definition for traceability. Today the definitions used by GS1 and ISO are much referred, also by the academic studies, and they can be even called the baseline of the traceability definition. One may point out that it is problematic that commercial actors have had such an influence on defining the terms. Surely it is rather an unconventional situation, hence normally academics are the ones that define such terms and then they utilized by commercial actors but is automatically problematic; hard to say.

Another conclusion that can be done is that traceability is a large entity, which requires cross-sectional co-operation at the organization to be functional. Again, there are two things that follow from this: potential for great improvements but also great challenges. However, because traceability has been taken account in every part of the organization the benefits traceability offers can be achieved extensively through the whole organization. These benefits were described in section 2.2 where the situation was flipped over by examining what different demands businesses could fulfill by implementing or improving the traceability system. A bit surprisingly the benefits of the traceability system brings to the company are “universal”, improved quality, improved customer satisfaction, improved operational efficiency are all examples that a company can achieve despite its field of business.

The main challenge which rises from the intangible nature of traceability is how it can be effectively implemented into the organization. Researchers have used contingency theory to analyze this challenge and came up with the solution that to be successful, each system needs to be tailored for the case company. It sure can be expensive and time-consuming but based on experts it is the only way. The situation with the traceability system is actually similar to ERP, they are both used to improve the operation of the company so that in the end the needs of the customer are satisfied. Therefore, whether the improvements that are pursued are made for internal or external reasons the focus should always be on the customer – how the improvement affects the company’s ability to react customers’ needs.

3. TECHNICAL SOLUTIONS

Based on the previous sections' sources, traceability, whether it is implemented internally or through the supply chain, has various possibilities and benefits. Depending on the field of business the best practices of traceability may already be easily available, for instance, food and medical industries have clear standards which are based precisely on best practices, but in the manufacturing industry most of the companies have their own traceability systems and policies. Despite those technical solutions for tracking and tracing, it can be assumed that different industries yet share the basic principles. Hence some research of how others have implemented traceability systems can be very helpful, after all, there is no need to reinvent the wheel.

Therefore, if technology is available and benefits are more or less clear, why traceability has not been studied and implemented more widely in different areas of businesses. One answer may be technological infrastructure, which is needed to run the traceability system effectively, which has not supported the implementation of traceability well enough. In this context technological infrastructure includes the internet, which enables information to flow automatically, and modern ERP, which processes and stores data. The development of technological capabilities has been fast in the last decades, therefore implementation of technologies like QR-codes or RFID is becoming easier.

This section describes different solutions for implementing traceability in spare part business. All of the presented technologies have been used successfully in different traceability applications in various fields. Hence the focus of this work is not on the technical features they are described at a basic level emphasizing more the business aspect. The section is divided into three chapters: technology level solutions, system-based solutions, and comparison of described solutions.

While discussing solutions at a general level it is hard to do a detailed and thorough comparison, especially when there are both technologies and system-based solutions included. In other words; there are no absolute values that could be used for comparison hence it is based on the theoretical review. For that reason, the comparison is based on more relative values against each other. Features that were chosen to be compared are listed below:

- Investment cost
- Operating cost
- Accessibility
- Suitability for spare part business
- Need of collaboration

From the listed features cost structure of the traceability system may be hardest to present at a general level, hence there are a lot of variables that are dependent on an environment, for example, the level of traceability, how much software needs to be customized, etc. In [57] have been formed assessment criteria listing for traceability systems in the food industry shown in table 1, which can be adopted into spare part traceability with small modifications.

Table 1 Costs structure of traceability system

Category	**Investment costs**	**Operating costs**
Time and effort	Information search Change management Test runs	Slow down Interruption of operations Additional reporting
Equipment	New purchase/installation	Upgrades
Training	Extensive, comprehensive	Ongoing
External consultants	For system choice	For specific challenges
Materials	Switch to new materials “system”	Labels and packing

3.1 Five technology solutions for traceability

Bar code

Barcode is a widely used technique to store a small amount of information in a machine-readable form. It was developed in the 1960s by the food industry as a solution to streamline the checkout process at the grocery store, and still today the food industry is one of the top users of barcodes, practically every single item at the grocery store has a barcode on it. In addition to the food industry barcodes has various commercial applications in different areas of business, for instance, in logistics and healthcare.

Since barcodes are so popular, there are also plenty of different practices and standards used globally, such as GS1, EAN (*European Article Number*), and UPC (*Universal Product Code*). The main difference between multiple standards is their capacity to store information, and the tolerance for errors, which are caused by printing. Figure 4 illustrates the EAN-13 barcode, the number that is encrypted to the code is always presented also below the code in numeric form. [24]

Figure 4 Illustration of commonly used EAN-13 barcode

Hence barcodes have been used for decades every ERP system has built-in ability to read and process them. Since the technology itself is commonly known there is no need for a long training period, which indicates low investment costs. Operating costs with barcodes are formed by fixed costs, such as the price of the software, and variable costs, such as labeling and personnel costs [58]. Again, the maturity of barcode technology decreases the operating costs with an assumption that ERP in use already has the ability to process barcodes.

The question of whether the barcode technology is suitable for spare part traceability is also important even it may easily be forgotten while considering only the costs. As barcodes are widely used in by the food industry, there are no implications why it would not be suitable for spare parts too, in-house only or through the supply chain. One challenge that may be a problem with barcode-based traceability system is the low capacity of stored data which can include only numbers in it. Necessarily it would not be problematic, but for sure it would limit the possibilities of how the system could be used.

In practice QR codes can be also identified as barcodes, regular barcodes could be called 1D barcodes and QR codes to 2D barcodes. In addition to QR codes, there are also several other 2D barcode formats that, are used, but QR is definitely the most used. In this work other 2D barcodes beside QR are not discussed, hence they do not differ from each other significantly from the matter of usability.

QR-code

QR Code, the abbreviation of *Quick Response Code*, is a two-dimensional bar code that was developed by the Japanese car manufacturing industry in 1994. It is defined by industrial standard ISO/IEC 18004, and even if it is property (trademark) of Toyota Group it is available for public use for free. [59] The basic function of QR code is equivalent to a barcode, it stores data, usually in a numeric or alphabetic form (*also web sites, pictures, etc.*), and originally it was developed to track the movement of car parts on the Toyota assembly line. QR code is formed from small black modules on white background (presented in figure 5), and they can contain up to 7089 digits or 4296 characters, which is significantly higher than regular one-dimensional or two-dimensional barcodes. [60]

Figure 5 Two QR codes which includes a) text b) link to web site.

The structure of the QR code is clearly visible in the figure above; three bigger squares are always placed in the corners of the code: they are used for positioning. From the figure 5b also a smaller alignment pattern can be seen in the middle of the picture, which are used when the amount of information gets bigger. Both of these features are used to positioning, which enables them to read it from any position extremely fast, for instance, upside down. [59]

According to Tretinjak QR code has several improvements compared to bar codes and other two-dimensional codes, which increases its affordances in the different business environments [60]. Some of the features are listed below

- High capacity data storage
- Can fit into very small size
- Kanji and Kana character set capability
- Dirt and damage resist
- Readable from any direction

- Low price

One feature worth noticing is the dirt and damage resistance of QR codes. Due to error correction that is done during the encoding phase, the code remains readable even as much as 30% of it is corrupted [61]. While this enables the use of QR codes in harsh environments, for instance, in workshops or factories, it comes with a certain price – higher error tolerance decreases the data capacity dramatically. The error correction level must be chosen during the code generation phase, so if the error tolerance is needed to be 30% code can store only 3057 characters which is less than half of the normal capacity.

In the modern world one “disadvantage” of QR code that can be identified, is that there is no “intelligence” behind them. In a way QR code is always unchangeable: after the code is generated it cannot be changed, but still, codes can be categorized into static or dynamic. Static codes are one hundred percent unchangeable, usually they contain text data or direct URLs. Dynamic codes instead are codes that contain shortened URL’s. These shortened URLs are products of service providers, which links the shortened URL to the landing site. This enables companies to have fixed shortened URLs which can be used at QR codes, and the URL of the landing site can be changed if needed. Dynamic QR codes are commonly used at marketing, but in static codes are more popular in manufacturing.

It is said that QR codes were specially developed to improve traceability in the Toyota Group in the 90s [59], but is the technology of QR codes still today relevant in the matter of traceability? In the food industry QR code is widely used, but mainly at the downstream of the supply chain, or in final products that consumer purchase [59,62]. According to [63], QR codes have an explicit potential in the customer interface, not just as a tool for traceability, but also as a tool for connecting consumers and producer together. They researched QR codes in the context of marketing and found that the QR code could decrease the communication barrier between consumers and producers, which would directly lead to increased customer satisfaction. It would be justified to conclude that similar results would be expected from the spare part business environment.

The costs of the traceability system based on QR codes can be estimated to be similar to a barcode-based system, most of the equipment (*scanners, label printers, add-ons to ERP*) can handle QR codes as well as barcodes. The major difference comes from awareness, potential of the QR codes may not be recognized as easily and may be unfamiliar for some people.

RFID

RFID, *radio frequency identification*, is a technology that is used for identifying and tracking goods by using electromagnetic waves. It is a small tag, which contains an integrated circuit chip and antenna, with the ability to send, process and, store certain information in it. Basically, it is used for the same purposes as barcodes and QR codes, but as a more technical solution, it also has quite a many new opportunities compared to printed codes. The technological foundation of RFID was developed already in the mid-40s, and commercial application has been available since 1970s. [64]

RFID tags are small, paper-thin labels that can be attached to any goods to be identified remotely. Every tag has unique identification information from the product it has been attached; information can be read with a specific reader that emits and receives radio waves. These readers are then wirelessly connected to back-office data processing system, for example, warehouse management system. [65] The described structure of the RFID system, also presented in figure 6, allows to do minimal data processing in the tags and readers, so they can be fitted into small size, and it also makes them easier to use on daily bases.

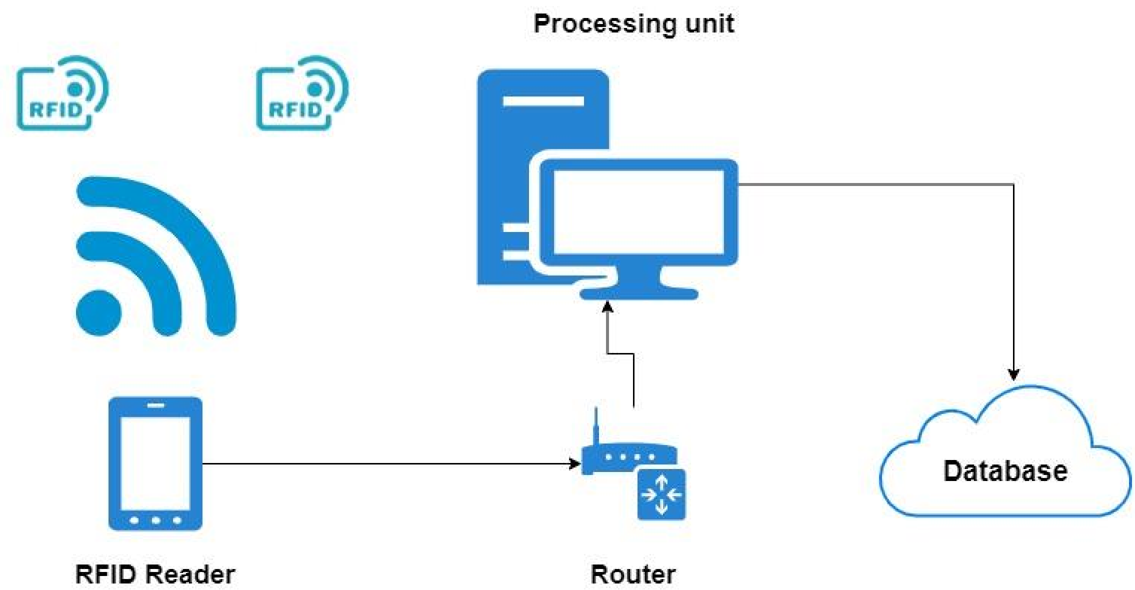

Figure 6 Simplified presentation of RFID system (modified from* [67]*)

Due to the different needs of different businesses, there are three types of RFID tags in the market; passive, active, or battery-assisted passive tags. Active tags have their own power source, on-board battery, and that allows them to periodically transmit their ID. Passive tags on the other hand do not have any kind of power source, and they get the energy from radio waves emitted from the reader. Battery-assisted passive tags include a small battery unit with them, and nearby RFID reader activates them to transmit their ID. [65]

The major difference between the three different tags is the reading distance. The passive tag can be read only from a short distance, which can be anything between 0,5 – 5 meters, so a visual connection to the object is required. While this limits the possibilities where it can be used, it also allows to pack it into small size, and it is commonly used for tracking and tracing in supply chain applications [65]. Active tags are highly readable even with 100m distance, which combined with the active transmitting feature, makes them suitable for online (continuous) tracking. Examples of active RFID tag applications can be found from various businesses; farm animals may have the active tag on their collar, so that the feeding machine can dose medicine for proper animals, road tolls can be charged automatically by identifying cars from their (active) RFID tags, cargo container can be identified by scanning the RFID tag during unloading at the harbour. Battery-assisted passive tags are used to the same applications as passive tags, but due to battery, they can be read from a longer distance. [66]

Wang describes in his study various benefits that can be achieved by implementing the RFID system, which are relatively comprehensive and independent of any area of business [67]. Wang's findings are listed below:

- Improve asset utilization by tracking reusable assets and providing visibility into their location and usability
- Improve quality control
- Improve performance by providing valuable information to ERP and MES (*manufacturing execution system*)
- Improve inventory tracking and visibility
- Improve MRO (maintenance, repair and operations) operations
- Reduce scrap and increase line performance by controlling operations more accurately with data collected from tags
- Deliver surgical precision in product tracking

As a modern technology RFID was expected to revolutionize traceability and product data interchange in the supply chain. It was studied a lot in the mid-'00s [64–66,68], and it has proven to be an efficient way to improve traceability in the supply chains, and onsite warehouses. According to Michael and McCathie, Wal-Mart implemented RFID technology in its supply chain, which decreased its supply chain costs 6-7 percentage, equaling about 1,4 billion dollars in total [66]. On a large scale one benefit that RFID allows is automatic reading and processing: Active RFID tags can be placed into trucks, so the system detects all the trucks near the warehouse. Also, all pallets can be read automatically during they are moved from the truck into the warehouse, which reduces the need for the workforce to register all shipments.

If RFID has been described as superior compared to 1D and 2D barcodes already fifteen years ago, why it hasn't replaced them yet? Studies have identified several barriers for adopting RFID technology and findings were surprisingly common to all technology adoption processes; cost, accessibility, and awareness of “new” technology [66,69]. Even the costs of passive RFID tags have decreased, being currently 0.05-0.25 cent/each, the price can be still considered relatively high for bulk products, whereas printed 1D or 2D barcode costs practically nothing. Also, in the manufacturing industry one challenge is that passive RFID tags will not work properly on metal.

Lack of awareness of RFID is surprisingly still affecting on implementation of RFID technology in many cases. Compared to traditional barcodes it has more restrictions, i.e. with metal objects or near water, which usually have a major effect on price and whole implementation. A common mistake also is to think that the RFID-based system does not require manual labour at all, which is not true, hence normally all the tags must be registered (*or linked*) into the right products in the ERP. [69]

While managers are considering the unit prices of RFID tags, it is good to remember that even the price would be too high for item-level, it can be utilized for in pallets or containers, yet those would already need active (more expensive) tags. In their paper, [69] describes the life cycle of RFID technology, and make a prediction that RFID will replace barcodes totally in the future, but before that, both technologies are available in the market, side by side. This conclusion is justifiable in the context of technology innovations generally, but 13 years after their study, their conclusion can be questioned. Is it possible that RFID will not replace barcodes after all, at least at the item-level.

NFC (Near Field Communication) is one commercially used application for the RFID technology that is used widely. It works wirelessly in close-range to transfer small amounts of data between two devices. While it exploits the RFID technology, the main difference is that in NFC one device can receive and emit data. Nowadays it is used in smartphones and credit cards, hence the amount of transferred data stays relatively small in payments. Brands like Bertolli and Johnnie Walker are using NFC in their products, yet not for traceability purposes but more as a way to connect customers to the company's website more easily. [70]

RuBee

Technology that is officially known as *long wavelength ID*, commercially called RuBee, is a two-way wireless protocol for data transfer. Sometimes it is confused to RFID technology even it has nothing to do with it. It was developed to work in harsh environments and in conditions where RFID tags won't work, such as near, or on metals or water. Even the protocol that RuBee uses was standardized already in 2006, it hasn't breakthrough commercially [71].

Sometimes RuBee is confused to RFID as they seem to work the same way, but actually the working principles are totally different, and the protocol is more common with WiFi than RFID. Instead of using radio frequencies, RuBee uses low frequencies, which are based on magnetic induction. This low frequency, in optimal cases 131 kHz, is the main reason why it is able to performance also in conditions where RFID cannot, it also penetrates walls and human tissue effectively, which radio frequencies cannot do. [71]

In addition to the working conditions RuBee has several other advantages that can be beneficial in some cases: All tags have a small processor and static memory, which allows it to store small amounts of data in it and send it periodically forward. All tags also have a built-in battery, so they can work in similar way to active RFID tags, yet the battery lifespan is expected to be over 10 years, hence low-frequency transmitting requires only very little energy. RuBee is also able to work on peer-to-peer, which means it is connected to near-by tags. This enables, for example, tags to share data to be stored temporarily or detect if one tag unexpectedly is moved outside of the range (object is stolen). Security features of the RuBee are also highly developed, even so high that the U.S. Military has utilized it in its applications. [72]

Despite the great potential RuBee has, it also has some features that can be considered as challenges or barriers on its way to beat RFID. Firstly, on a large scale RuBee is remarkably slower than RFID, it is able to read only 6-10 tags in second, while RFID readers can reach 150 tags per second. Such rates make RuBee impractical for most of the medium or large supply chains. Another major barrier is the price, which is partly caused by a monopoly situation. Since there is only one company that manufactures RuBee tags, they control the price and the technology – the price of RuBee tag is estimated to be higher than the passive RFID tag but lower than the active RFID. The monopoly situation also has a huge effect on the system level: operating costs of RuBee-based system can easily be increased to very high, hence the user is 100% dependent on the manufacturer of the RuBee. [72]

As mentioned, so far RuBee has not break through commercially, even if it has some clear advantages compared to RFID. One indication of its potential is its usage in the U.S. Military, where it has been utilized in various applications, such as tracking weapons and explosives in warehouses. In 2019 company behind RuBee announced that they deliver 16 000 RuBee tags to the Estonia Defence Forces to be attached to riffles [73]. This could be seen as an indicate that the company is shifting their focus from normal B2B markets to military markets.

3.2 Two System-based solutions

Internet of Things

IoT is for sure one of the most discussed technology over the past few years, as it can be utilized almost in any field of businesses and manufacturing to support data and information flow. What makes IoT different from previously described technologies is that it is a more generalized term – umbrella term – that can include different wireless technologies that connect physical products together via the internet, allowing real-time and automated interaction, controlling, and data sharing. Bluetooth, ZigBee, RFID and wireless sensor networks (WSN) are much-used technologies in IoT applications [10]. For industrial applications sometimes IoT term is used, which stands for *Industrial Internet of Things,* it is basically the same thing as IoT, it just underlines the industrial environment [74].

Due to the abstract nature of IoT, there is no single established definition for it, which enables using various techniques and technologies in IoT applications. One feature that is essential to all applications is their “intelligence” or algorithms that are using the data collected from sensors or devices: data is the thing, the core of whole IoT. Collected data is presenting the current real-world situation, which is then analyzed and processed. From large datasets, algorithms can find patterns that are extremely hard to find by humans, which then can be used for development purposes.[10]

To understand the difference between IoT and other techniques that have been described previously, IoT can be presented as an enabler of the ecosystem, which is consisted of several layers. Figure 7 illustrates the layered structure of the IoT ecosystem, above the cloud computing layer the business level could still be added.

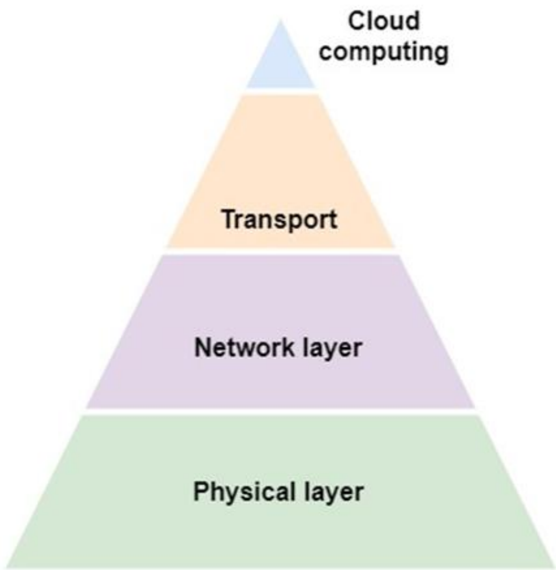

Figure 7 Conceptualized IoT ecosystem structure (modified from **[12]***)*

In the context of traceability, IoT solutions can be utilized for tracking and tracing valuable items such as containers or pallets through the supply chain at same time when the movement data or temperature inside the container is collected. There are already various applications where IoT is used effectively as it collects traceability data among other types of data, hospitals, for instance, use IoT applications to track and develop their patient and material flow inside their hospital buildings. [74]

As can be expected, IoT-based systems are relatively expensive compared to RFID or QR code-based system, since the IoT-based system usually requires quite a lot of sensors. Continuous internet connection may be expensive to uphold, and to work effectively the IoT system requires stable IT infrastructure to support it (including software and hardware). If current IT infrastructure cannot offer sufficient support, investment costs can easily raise too high for the traceability system.

Blockchain

The concept of blockchain was introduced in 2008 as it became the foundation of internet-based cryptocurrency Bitcoin. While the main driver for the development of blockchain technology lies in cryptocurrency it also became a popular topic of discussions in many fields of business, such as in logistics and finance business. The main idea with blockchain is to get rid of centralized trust authority by using a distributed database which stores all the transactions in real-time, for that reason it is commonly called “distributed ledger”. In all its simplicity: blockchain is a method to record data – and once any data has been recorded, it cannot be changed. All transactions are stored in blocks and several blocks are linked together as a chain. A distributed database enables all participants to observe transactions, so centralized trust authority is not required to guarantee authenticity. [75]

A single block in the chain is formed through specialized mathematical operation and linked to the previous block by using a hash function. In addition, that hash value uniquely represents the transaction, it also represents the ordering of every block. It is also one of the cornerstones of the security of the blockchain architecture: if anybody is trying to alter a transaction it would change the hash value and the chain would be broken. A single block contains also a timestamp and a small amount of additional data which are used for authentication purposes. A block can be added to the chain after it has been compared to the database and once it has been confirmed by a sufficient number of nodes (peer users). [76]

Due to the nature of this thesis work, it is not necessary to discuss more the technological features of the blockchain. More relevant is to consider what benefits can be achieved by implementing it and can be utilized in the spare part business to improve traceability. Already there are several applications in the food industry where blockchain technology is used for quality management purposes, also pharmaceutical and mining industries have started to investigate possibilities of blockchain technology as a tool for proof-of-origin [7].

According to Hastig and Sodhi, blockchain-based traceability systems are likely to become more common in the future, yet they notice that there probably will be other technologies beside it [7]. This is in line with conclusions that were made from the IoT-based traceability system: the most suitable system includes different elements and technologies side by side. For example, IoT and blockchain may be more suitable for bigger and more expensive products, while barcodes and RFID are superior in cheap bulk products. After all, presented the conclusion should not be considered as surprising, since it is very much in line with the contingency theory, which is presented in section 2.3 – different situations require different solutions.

So far traceability studies related to blockchain technology has focused mainly on the food industry, but there are a lot of findings that can be applied to other fields of business too, for example, their findings about business requirements of a blockchain-based traceability system, which are

- Meeting stakeholders needs, such as traceability and transparency
- Curbing illicit business processes (i.e. frauds)

- Improving sustainability
- Increasing operational efficiency
- Enhancing supply chain management (i.e. improved information flow)
- Sensing future trends

As can be seen, listed requirements are identified at a general level, and they can include various things as sub-requirements, but still, the big picture can be perceived: there are big expectations for blockchain technology. The effects on the business can be huge in the best-case scenario. However, Hastig and Sodhi underline that any of the benefits are not coming by themselves but they are the outcome of hard work. What it really means is that blockchain, like any other technology, is not single-headed key to success, but it can be used to achieve targets as higher operational efficiency. Rather interestingly Hastig and Sodhi state that even 80 percent of the blockchain implementation efforts is about business process reengineering, which indicates that the technology itself is relatively inflexible. [7]

The assessment about how well blockchain can be utilized for the spare part business is still unknown, hence there is no specific research on that. On the other hand, based on the presented sources there are no implications why it could not be suitable also for the spare parts. However, the main challenge with spare part traceability and blockchain would be the large variety of products and their prices. One may ask how blockchain can be implemented in the food industry, where unit prices are much lower than in the spare part business. The answer is that the food industry is actually not tracking goods at item-level but at batch-level. So as a conclusion it can be estimated that blockchain-based traceability may be a prominent option in the future, but at its current state it would be too complex for spare part traceability.

3.3 Comparison of presented technologies

While traceability has become of greater interest in many fields of business, technological development has also made it possible to trace products even at item-level through the complex supply chains. Based on the presented sources in this section can be noticed that all these five techniques have possibilities and great benefits in a proper environment.

The importance of analyzing the current situation and environment cannot be underlined enough: what are the expectations for traceability, is it utilized internally or through the supply chain, what are the technical capabilities of the organization – optimal traceability solution is always dependent on environmental factors.

Table 2 Comparison of selected techniques

	Investment costs	Operating costs	Accessibility	Suitability for spare parts	Requires high collaboration
Barcode	low	low	high	mid	No
QR code	mid	low	high	high	No
RFID	mid	mid	mid	high	No
RuBee	high	high	low	high	No
IoT	high	high	low	low	Yes
Blockchain	mid	mid	low	mid	Yes

As can be seen from the presented table, barcode and QR-codes could be implemented most easily, hence they do not require large investments in new infrastructure or training. Nevertheless, with barcode it is justifiable to doubt if they can include enough product data behind them. As were presented in section 3.1 the capacity to store data is relatively low with barcodes, and the data structure is also very restricted. It surely is possible that the data structure of barcodes is actually a bigger challenge while considering the suitability for spare part traceability. The reason is that each (number) slot must be filled with a number, so it is likely that a company would have to re-engineer their whole product numbering system.

The most significant difference between QR code and the regular 1D barcode is surely the data capacity and that QR code has no data structure limitations. In traceability applications for spare parts, the data capacity is one big advantage because then for the customer can be offered more data than just part ID-number. The main challenge that usually comes up with QR based traceability systems is the fact that printed QR code cannot be changed. A bit surprisingly it can be estimated that with spare a part that it is not considered as big problem, since the purchasers of spare parts are usually the end users so there is no need to add or change anything. Therefore, it can be estimated that QR is relatively suitable technique for spare part traceability.

RFID and RuBee are techniques that are much used in various traceability systems, so they have proven to be effective and reliable. Different studies, especially from the food industry have shown that RFID can work even in harsh environments. The practical challenge with RFID is that each RFID tag must be “paired” with the product to which the tag is attached. When the number of labeled items gets high the labour work that is required to operate the system also gets high, which affects operating costs and usability of the system. RuBee most likely has even more benefits and affordances than RFID, but as was discussed in section 3.1, the company behind it has focused more on military business, which raises an important question: is the technology even available for commercial actors easily. Assuming it is, all cost of RuBee based system would be expected to rise extremely high, hence there would be no price competition. Compared to less technical options – barcode and QR code - the estimation is that RFID would have a bit higher investment and operating costs, especially in Cimcorp, hence normal passive RFID tags will not work properly when they are placed directly on metal, which would be the case in Cimcorp.

The last two techniques in table 2, IoT and blockchain, are both relatively new techniques, yet, already they are both used in the traceability applications successfully, and especially blockchain technology is much researched by academics and commercial actors. The stage of maturity is also the main reason why they are assumed to be expensive and labour intensive, at least in the beginning of implementation. The fact that both are based on high technology innovations also indicates that they would require much education, among employees, but also for customers.

The reason why IoT and blockchain are both considered as system-based technologies is that they both require some additional systems besides them. So even both are in itself technologically complex solutions, together with other systems and technologies these systems can form really complex IT architecture which can be challenging to manage. For the same reason, it is assessed that if such systems cannot be operated profitably or effectively in small or even in mid-size companies. For the question about how suitable they are for the tracing spare parts through the supply chain answer is simple, IoT based solutions are not considered suitable but blockchain is. The estimation about blockchain is based on the fact, that it is already used for traceability systems, and there is no logical reason why it could not be used with spare parts too in the future.

After all the final conclusion about which technological solution is the most suitable for Cimcorp is relatively simple to make: QR codes. Both RFID and QR have good features that could be used effectively to trace spare parts, they are also much used in industrial applications, so they are commonly well known. The main reason why QR is estimated to more suitable than RFID is its simplicity, it does not require big investments from

Cimcorp or its customers, and it is better known technology than RFID and it is super easy to use.

4. IMPLEMENTATION PLANNING

The main target in this thesis work is to increase the customer value by streamlining the described spare part process. At grassroots level one major challenge in this process has proven to be the identification of the needed part. In a complex system, for example, there can be more than 10 different servo motors, which all can look externally almost identical. Before the customer can order a new part, the old part needs to be identified (serial number and ID number). By implementing QR-codes this identifying process will get much easier, and if also enables to provide other information too, such as mandatory safety documentation and possible expiration dates.

Implementing new technology in a global organization is always challenge, that requires time, detailed planning and resource allocation. The unpleasant fact learned from practice is that bigger technology implementation projects have bigger failure rates, over all it is estimated that over 50% of all technology implementations fail to meet their targets. In general, the challenges of any technology implementation projects are very similar to challenges of ERP implementation that were described earlier; lack of efficient communication and support from managers. Based on the multidisciplinary analysis made by Rizzuto and Reeves the challenges related to technology implementation processes are mainly attributed to “people issues” rather than technology. [77]

The implementation process of new technology can be divided into three phases; initiation, implementation, and institutionalization. During the initiation phase, primary activities are related to research and exploration of various options and their suitability for the current situation. The implementation phase focuses on introducing the new technology or process for the targeted users, it can include several iterations, where the new technology or process is developed to match better with the requirements of the company. Rizzuto and Reeves identify the implementation phase the most important phase for a successful implementation. During this phase, employees must be convinced of the new technology and its necessity. In the last phase processes and routines are integrated and fully utilized in the organization. [77]

Klein and Knight (2005) have studied the implementation process of technology innovations in organizations, and they identified six main barriers that organizations usually face [78];

- New technologies are usually unreliable and imperfectly designed, so they have bugs and inconsistencies.

- New technology is more complex than the one that is in use.
- Decision to adopt new technology is made higher in hierarchy, while targeted users may have great comfort to status quo.
- New technology requires people to change their routines and norms, sometimes even role at the organization.
- Outcomes of new technology can be seen not until over a period of time.
- Organizational routines and norms foster maintenance of status quo

The findings of Klein and Knight are in line with Rizzuto and Reeves; most of the challenges are related to individuals and their ability to adapt to change, and most of them can be overcome with active managerial actions. These actions are, for example, sufficient training, continuous dialog between targeted users, and managers and proper resource allocation.

This chapter introduces the creation process of the implementation and development plan. The case company is discussed more closely, selected part of the organization and processes are introduced at the general level as a background.

4.1 Description of the case company

The history of Cimcorp was started as an automation and robotic division of Rosenlew Ltd. in the early 1970s. At first, they developed and provided automated production systems for colour picture tube factories, and soon it became their main and most reliant business area. In the late ‘90s, when the business of colour picture tubes started to decrease, Cimcorp renewed its business strategy and started to provide automated manufacturing systems to food, beverage, and tire industries. Nowadays order picking systems for food and tire industries are the main business of the company.

During the 21st century, Cimcorp has become globally the top provider of automated manufacturing and picking systems for the tire industry, their market position was strengthened even more by the acquisition of RMT Robotics in Canada in 2010. In 2019 seven of the ten biggest tire manufacturers around the world, among several smaller ones, are customers of Cimcorp. For tire manufacturing Cimcorp can offer end-to-end solutions, which can include manufacturing planning, manufacturing systems, indoor logistics and automated order picking from warehouse.

In 2014 Cimcorp was acquired by privately held Japanese company Murata Machinery Ltd. (later referred Muratec). Muratec operates in five business domains (*textile machin-*

ery, logistics and automation, clean rooms, machine tools, and communications equipment) and in the field of logistics automation the company is one of the top operators in the world. Since the acquisition, the business of Cimcorp has increased constantly, compared to the year 2014 Cimcorp has doubled its revenue in 2019 up to 130 million euros.

What differs Cimcorp from its competitors is its ability to provide end-to-end solutions or more specified projects, depending on the needs of the customer. Figure 8 presents the process of finding an optimal solution for the customer through the discussions, analysis, and simulations.

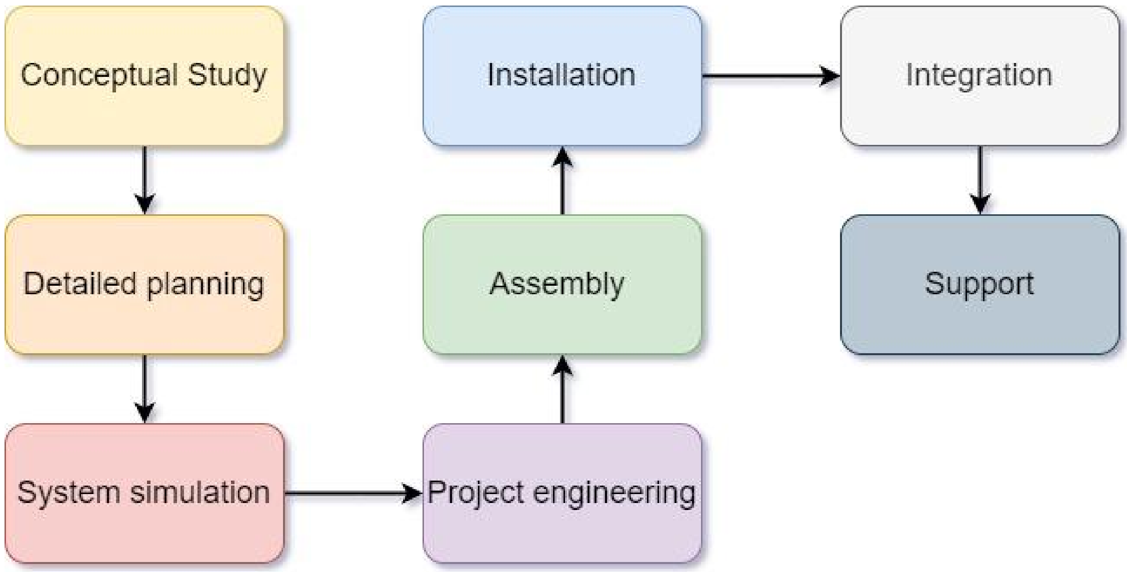

Figure 8 Business process of Cimcorp

Later in this chapter the customer support department (in figure 8 referred simply support) is described; the organization and its main functions are introduced, including spare part function. Furthermore, spare part function and its processes are discussed more closely.

Customer Support

The role of customer support is relatively easy to underestimate since it is usually just the “last step” in the business process. In Cimcorp organization, that could be described as a project management organization too, the nature of customer support is clearly distinct compared to previous steps in figure 9; Firstly, customer support provides technical support till the end of products’ lifecycle, not just during the engineering and production phase. Secondly, customer support may have the biggest single effect on customer satisfaction during the product lifecycle. What it means, is that even the majority of the project is managed well, a bad experience with customer support can decrease dramatically the level of customer satisfaction. In recent years, Cimcorp have extensively developed the customer support department, hence the role of after-sales and customer support has been recognized as strategically important.

Customer support consist of four functions; *service management, project management and engineering, spare part management and project sales*. Service management is responsible of managing the maintenance operations, both coordination and shop floor management at the customers site, therefore they also provide technical support to customers if needed. Project management and engineering team is “the muscle” of aftersales projects, the team has project managers, automation engineers and software engineers. They execute the actual aftersales projects, which usually contains software and automation (logic) modifications and updates. The normal scope of aftersales projects is roughly up to half million euros. The sales team is, surprisingly, responsible for selling projects, including updates, retrofits, new entities into larger production systems.

As can be noticed, customer support has its own project team even if there is also a project management department in the organization. The main reason for this can be found in the Cimcorp business model: the lifespan of normal project delivery can be anything from 12 to 36 months, so managing those kinds of projects requires relatively precise planning in advance. Yet, projects of customer support are by their nature much shorter, and by separating those projects to own team, customer’s need can be fulfilled much faster.

While the big trend in the manufacturing business has been the increased share of services [79], it has not affected Cimcorp as much as could be expected. At the same time, another trend is to insource crucial operations, such as day-to-day maintenance of production equipment. To tackle both problems Cimcorp has decided to develop current organizations as follows; Customer support department has been strengthened, so that in the future more services can be offered for those who are interested. Yet, Cimcorp has also founded small service organizations near its global customers, so that, for example, maintenance work can be done together with Cimcorp experts and customers inhouse maintenance staff. In addition, these small service organizations are a great way to study new markets with relatively low risk.

Spare Part

As mentioned, the spare part is one of the four functions in customer support. It stands as an example of organizational development that Cimcorp has actively done in recent years; spare parts were differentiated into their own function some years ago. This was a major step towards being able to provide more, and better services to customers in the field of after-sales and warranty management. It also made it possible to manage and develop tasks and processes related to spare parts. Below, in figure 9 is presented the process of spare part service in its current form.

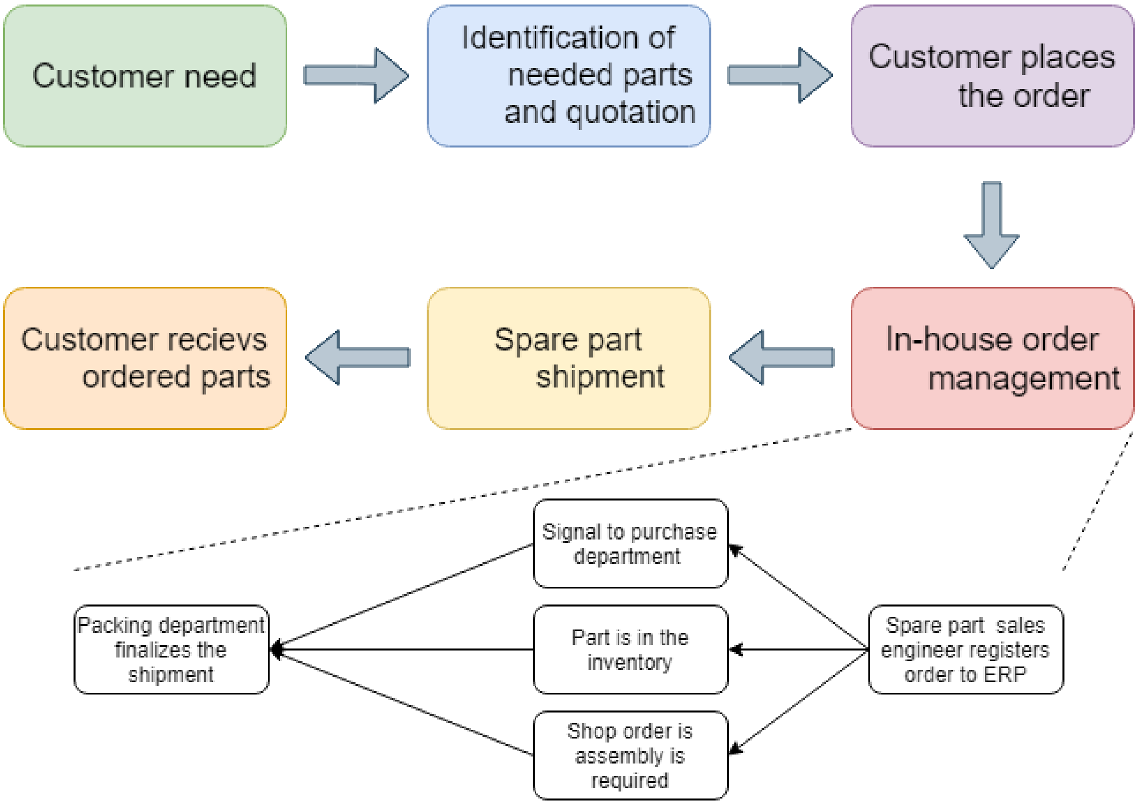

Figure 9 Spare part process of Cimcorp

The process of spare part functions in many cases starts from the customer, they recognise a need for spare parts, it may be caused by arbitrary mechanical failure or planned maintenance repairment. A standard procedure is that the customer stocks critical parts on-site in their own warehouse, amounts and assessment of which parts are critical are fully made by the customer. Usually at the beginning of a new project a customer purchases a spare part package that includes most used and critical spare parts for the customer's system. Especially new projects have proven to have great potential to increase the sales of spare part packages since it is easy for the customer. Hence every system requires some spares in the long run, the customers tend to choose the easiest way if the price is considered reasonable.

After the customer contacts the spare part sales engineer, or alternatively to service coordinator, there usually are some things that needs to be clarified, such as what is the need (identification of customers' systems and parts in it is essential) and how urgent their need is. Then spare parts sales engineer starts the in-house process in their ERP system by registering the customer's quotation. As can be seen from the figure 9, there are three options how the process can proceed: part can be ordered, if it is not stocked. If it is available on the stock, then is just picked from there. Cimcorp also offers assembly service for certain products and spare part entities, which can contain mechanical and electrical assembly work. By providing the assembly services to customer, Cimcorp can be assured about the quality of the final (assembled) product, it also makes spare part process easier to customer, since all the spares are one hundred percentage ready to use at the customer's site.

4.2 Choosing the technology

As have been presented in section 3.3, there are two different techniques, QR-code and RFID, which were estimated to be the most suitable for Cimcorp to improve their product traceability. In addition, both of them have relatively small investment costs, they both are capable to operate in harsh environmental conditions, such as hot temperatures and high humidity which occurs, for example, in tire manufacturing facilities. While it is possible that some customers of Cimcorp do not have an internet connection on their manufacturing sites, it will not affect dramatically on either one. However, in the future the lack of internet connection can be seen as a clear challenge. The limitations of the chosen system will be described later on more precisely.

After a theoretical review of six different solutions a decision was made to look into both (top 2) options a little more, even QR-code was already the one that was recommended. The main reason for additional research was to consider both options in the terms of spare part business more carefully. Since the majority of source material discussed technical solutions from the point of the food industry, this kind of hands-on research felt reasonable. Another reason was that there was an excellent chance to benchmark RFID technology in action and see how it is used in automated warehouse for small goods used in manufacturing and construction.

The benchmarked system can be described as an automatized warehouse system that is located on the customer's site and can be used freely by authorized personnel whenever needed. In many cases, all of the shop floor staff have access to such warehouse, so it can be used as easily as normal/own warehouse. All items are attached with passive RFID tags and they are automatically read during the checkout. From the customers point of view, the biggest advantage of RFID technology is that tags can be red wirelessly. This enables to read all tags at once during the checkout, but it also enables to monitor the stock continuously – if any good is moved (attached with tag) in or out, it is recorded on the log. For the company that operates the warehouse it provides real-time information about stock levels and enables to rent goods from the warehouse too, billing starts from the checkout and stops after the item is returned. This is popular, for example, with expensive machines that require regular maintenance.

While interviewing the representative of the warehouse operator, the benefits and the challenges of RFID technology came up distinctly. Absolutely the biggest advantage is the accessibility: RFID makes the purchasing process extremely easy for customers and requires very little training or guidance, the central warehouse is automatically informed when a re-order point is reached at the stock, so stock-outs are rare. From the operators' point of view, RFID tags are easy to install and there have been barely any problems with them. Surely there have been some challenges too, mostly with goods that have a metal (usually aluminium) body. While the challenges of RFID technology have been already discussed in different research papers, it was valuable to see RFID in action and realize how easily metal surfaces can disturb it.

Hence the majority of the spare parts that are dealt with are made from metal alloys, it became quite clear during the benchmark that RFID was not a suitable option for Cimcorp. For this reason, there really was no need to benchmark QR codes more closely since all other options were ruled out.

4.3 Requirements determination

So far QR codes, among other researched techniques, have been discussed only from the standpoint of spare parts. Hence QR codes may have potential in somewhere else inside the organization, such as any new technology that is implemented into the organization, the first step after choosing QR was to investigate other affordances at Cimcorp. In large organizations it is obvious, that all affordances cannot be found all at once, but it is still important to map out current situation so that different requirements can be taken into account already during the planning.

Different requirements for QR technology can be considered from two aspects; what are the technical requirements and business requirements. During the implementation planning the technical requirements can be considered more relevant since they might have an influence on how the implementation is done (i.e. does QR implementation require some new software), and what features should be implemented. Yet, usually business requirements must be considered first to fully understand the current situation/problem and after that technical solutions can be considered more carefully.

Warehouse management was one function that recognized an opportunity to improve their process with QR codes. Their main goals, or *business requirements*, were quite much in line with what have been presented already (spare part function's requirements);

improve traceability of the products and streamline the information flow. At warehouse QR codes could be used at pallet labels so that labels could be read from ground while the pallet is placed on a shelf. Since there are no fixed locations for most of the parts at the Cimcorp warehouse, QR could ease the work of warehouse workers when they are not sure what the top shelf pallets contain. On a practical level there are two options for how QR code could be used in this kind of situation; static or dynamic QR. In the best-case scenario pallet would contain dynamic code, which was directly linked into the Cimcorp ERP system, so that all relevant data, such as stock balance can be seen easily.

Another function that was identified as a potential user was the production or project function as it is called at Cimcorp, which is responsible for all new projects, including systems planning, engineering, and manufacturing/assembling. By implementing QR codes into new projects too, the benefits received from QR codes would be highest - for the customer and for the Cimcorp. This estimation is based purely on the fact, that if QR codes are used in spares only, it takes quite a lot of time to spread broadly. It is also likely, that the project function could not use QR codes as it has been planned to use with spares; attaching QR code on every part is not reasonable. One option would be to use QR code on one larger assembly so that it could include a listing of all parts used in assembly. Nonetheless, it is safe to assume that the project function does not have any special requirements for QR technology that should be taken into account during the implementation planning.

As a summary, it can be said that several departments/functions in Cimcorp could implement QR technology, and the requirements are very similar between all of them; codes must be capable to include plain text and possibly URL in the future. In terms of implementation, the requirements for the QR technique are relatively coherent which should make the implementation process easier.

4.4 QR and Spare part process

After the potential of QR codes were discussed among other process owners, the most prominent usage, along with the spare part function was recognized at the warehouse operation. However, at the first stage of the implementation process QR technology was limited only to spare parts. The main reason for this was to test the system on a smaller scale and see if it works as planned, it felt also important to schedule time for urgent fixes and developments. Also, there was a large development project going on at the warehouse, which had higher priority, so it felt reasonable to move forward without the warehouse function.

The first step on actual implementation planning was to redesign the spare part process so that it included the QR codes. While the actual changes at the shop floor would be relatively small, one target at the implementation planning was to develop a spare part process step by step, so that each change could be adopted easily. It is also well-known fact that bigger changes always cause some resistance among employees, so smaller changes at each step would increase the success rate of the project. The planning of the improved spare part process was executed as follows: at first, three different options were planned, each had a different idea on how QR could be utilized. One was chosen as the most prominent option and preparations implementing it into action was started. By choosing one option, it became also possible to start planning on the next phases of the project. The described planning process is presented in figure 10.

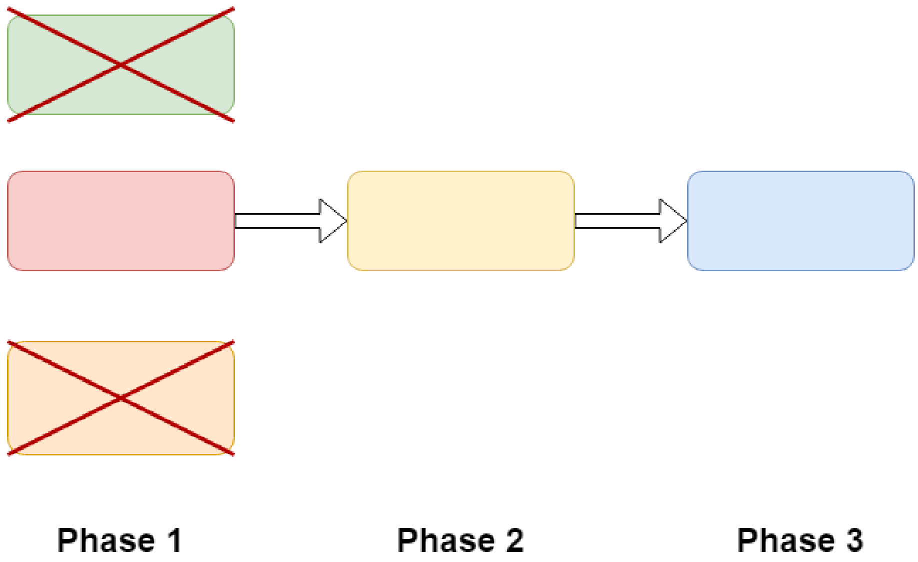

Figure 10 Illustration of implementation and development plan

Hence detailed process descriptions and flow charts contain business sensitive material, they cannot be presented or described more closely in this work. Although, one thing that can be described more are the factors that affected the decision. All three options were estimated from two perspectives; how does it affect Cimcorp and how it affects customers. From the Cimcorp point of view, it would be ideal that the new process would not require more manual work than the current process, and also material flow at the shop floor (picking and shipping spares) should not get much more complex. Because the QR code will be anyway placed on the spare part label, the process of labeling can change much, but the question of when different types of spares are labeled is the one that can complex the process.

While considering the customer point of view, the biggest single factor that needs to take into consideration is usability/user-friendliness. Usage of the QR system must be simple enough so that it can be utilized all around the world among different field of businesses. The role of usability is also vital while considering the effects of this project on customer satisfaction: QR code has great potential to improve traceability and thereby customer satisfaction in the area of spare parts, but it requires that customers adopt QR codes widely.

4.5 Pilot testing

In every development or implementation project, pilot testing has important role, it can be seen as a gateway from the drawing board to execution. Normal procedure is that piloting is done in a controlled environment where process, system, or product can be tested in action, and make sure it works as have been planned. In the original project, plan piloting was planned to do so, that it could be reported at this work, however, unexpected technical challenges delayed the schedule and therefore this section only describes how the pilot testing is planned to be executed. Before the actual pilot testing can be executed, there are still couple of things that needs to be taken care of:

- Configuration on new Zebra ZT230 printers.
- Ensuring that all relevant data from ERP can be used at QR codes.
- New spare part labels must be designed hence QR code cannot be fitted into current label

The configuration task was designated for the project manager of this project who is responsible for all technical matters related to QR implementation. Quite fast it became up that connection straight from Cimcorp ERP system to the Zebra printer was challenging to set up since it would have required comprehensive knowledge on *Zebra Programming Language* (ZPL). After some consideration it was estimated that in the long run easier and cheaper way is to acquire 3rd party software called BarTender that can be used as a complier from HTML to ZPL – HTML knowledge in the organization of Cimcorp was strong. BarTender receives data on HTLM form and generates QR code with chosen parameters (i.e. damage resistance level), then the data is compiled and send on a printer.

Another thing was important to make sure, that all the data that were planned to be used at QR could be accessed at ERP and transferred to the actual QR code. This was also designated to the project manager since it was only a matter of how it can be done, spare part function was already ensured that data itself could be presented without compromising data security or competitiveness of own products. Already there are some data presented at the spare part label, which are required by customs authorities, so from that standpoint data security is not a game changer, it is just something that must be taken into account while planning.

The spare part label itself had to be redesigned too, since the current version does not have space for a QR code. Two different layouts were designed (presented in appendix B), major difference between them was the size of the QR code and the entire label: the smaller one was 100*50mm including 25*25mm sized QR code, the larger was 104*64mm with 30*30mm QR code. One thing that was considered carefully was the size of QR code: scanning distance shortens while the size of QR is decreased. Yet, in a manufacturing environment, and especially with spares parts it can be assumed that the reading distance is not as important feature as in commercial usage. The assumption is that the part, and therefore the QR code also is in very close range, hence the broken part must be anyway removed and replaced.

After the action that is described above has been taken care of it is possible to run the pilot. The main targets for piloting are listed below:

- Make sure that labels work
- Make sure that the process works
- Introduce new label printer to employees, and train them to use it.

One important feature that must be examined during the pilot testing is how well the planned label form acts in a real environment: the label is two-pieced in a way that the QR can be removed and attached to spare. Based on the inquiries that were sent to label retailers such a layout is doable, but it requires little preparation work (a process called *perforation*). After that the QR code can be torn off from the label easily, still containing the adhesive surface on its backside so it could be attached on a spare. The most important thing to test with the labels is to examine how labels can be placed on the spare part package while conserving the adhesive surface of the QR code part. If turns out that such a label design requires too much detailed work each time it is placed on a package, the design must be reconsidered.

Another important thing that needs careful consideration during the pilot testing is the process that starts when goods are received and placed on the stock and ends when parts are shipped to a customer. There are a couple of things that were on discussion during the process planning: what is the right time to label the spares, and who in the end attaches the QR code on a spare, warehouse worker at Cimcorp or the customer? The best outcome could be achieved if these questions are considered together with a customer. Therefore, piloting should be done in a co-operation with one customer. The customer's responsibility would be to report how they are able to work with QR codes (read them, etc.) and comment if there is something that should be done differently. Such co-operation does not necessarily need to be huge and long-lasting, already few shipping's and few meetings would do the trick.

4.6 Future development

As have been mentioned, one target for this implementation project was to create a solid plan for the implementation and development that could be executed step by step. The main reason for this was current situation at the organization; the spare part department has their hands full with the normal spare part business and this development project was planned to be handled beside the normal workload. This in mind a three-step plan was created: phase 1 (presented in previous sections) would include all the actions that are related to actual implementation, such as planning, piloting, and institutionalizing the system at the shop floor and with the customers. In this section phases 2 and 3 will be described more carefully: what are the targets of both phases and how they can be achieved.

While discussing the implementation and development actions, it is important to point out that it is completely normal, and even highly expected, that there will be a gap between theory and practice in projects like this. What it means is that plans are easy to make, and different tasks can be easily divided into three phase – linearity and consistency is easy to uphold in the paper. For example, in a paper three phases can be easily divided into own entities, but in practice some actions may be temporally overlapping. However, reality usually ruins good plans, since there is always something that was not expected, circumstances may change, etc. Of course, one feature in a good project plan is that it can adapt to changes and somehow is prepared for unknown challenges. It is obvious that stating cannot be used as a disclaimer, but it is something that needs to be recognized.

Phase 2

The first phase of the project was quite precisely limited, it was only planned to cover the implementation and institutionalization of the QR technology in spare part operation in the main office. For that reason, the second phase contains a variety of different activities, from which some could have been done already in the first phase also. The main targets of the second phase are listed below, once they are specified, they are analyzed more closely

- Implementation of QR codes into the spare part process in Canada (CCNA)
- Implement QR codes to production and warehouse operations in Ulvila (CCOY)
- Make all customers aware of QR codes
- Create a web portal for sharing relevant product data

On a general level, all development actions of the project can be divided into two categories: the ones that are related purely to QR technology implementation and ones that are related to traceability on larger scale. Such categorization may be useful while perceiving the bigger picture and proceeding of the project, during the first and second phase it is vital to use money and time to create the “infrastructure” for traceability. As always, the importance of foundation is big, QR technology itself has only instrumental value for this project, but still, it can be considered as a critical asset for achieving the main target – improved traceability. This categorization is also good to keep in mind during the development since if the third phase still requires much effort on building the infrastructure it is a sign that the project may be moving forward too fast.

From the beginning of the project it was clear that new processes and technologies must be first tested at a single location and after it has been proved to be functional and efficient it could be scaled to cover the global operation. In practice, the Cimcorp operates globally all around the world but spare parts are warehoused and shipped to customers from two locations from Finland and Canada. In the ideal situation the improved spare part process, which includes the QR codes, would be copied straightly from Finland into the action to Canada. However, the situation is not that simple hence the original processes are not identical. There are a couple of reasons for that; firstly, the Canadian operation was founded by an acquisition of local robotics company and even the majority of the processes have been unified there are still some differences. The second reason is that the whole operation in CCNA is remarkably smaller than in Finland, which means that some processes and practices may be too heavy to use for them and cause inefficiency.

One way to solve the described problem is to combine some process re-engineering and copying from Finland. In that process the spare part manager of the Finnish operation would be required to work closely with Canadian colleagues so that the optimal solution can be found. It is possible that some kind of trade-off within this project must be done between traceability and process similarity depending on which is valued more. For sure at this work it would be easier to prioritize traceability higher, but the situation must be considered carefully before any decisions can be done. Due to the operation in CCNA is remarkably smaller, the implementation itself should not be that challenging, the great challenge is to decide what should and should not be done. As the second phase of the project starts it would be very important immediately to work with this matter, hence without the infrastructure the further development actions cannot be executed.

While the implementation work is done in the spare part function in Canada, at the same time would be important to expand the usage of QR codes in the Finnish operation too. As have been discussed in section 5.2 it is important to utilize QR codes to be used already at the production phase too. From the customers' point of view this would be considered as extremely important because then a customer could benefit from QR codes through the life cycle of the manufacturing equipment. If QR code usage would limit only to spare parts, it could take even years before a customer could benefit from them properly.

The major challenge with QR implementation into the production, and for all further development actions, is the lack of a project manager. So far, the process owners have been responsible for the progression of the project, but when the project requires more people and processes to be included the project manager becomes crucial. The main job that project manager would have is to take care of the coordination of different interest of different processes, she/he would be also responsible for coordinating the planning of web-portal that were mentioned earlier.

As said, the supply chain traceability is based on the ability to collect and share the data effectively. Cloud services have made data collection and sharing super easy on these days, in theoretical level data sharing is relatively easy to put in practice too, but in real life the manufacturing environment can be a hard place to get access to that data. The QR codes itself are robust and functional in many different environments, but the data behind them is basically just in text format, which means that the data itself is also quite robust. As a solution to that, the most common way is to use QR to store URL address, which leads to manufacturer's website. Therefore, some kind of web-portal or e-commerce sire would be beneficial to Cimcorp too. It would be an effective platform to serve customers and a platform that could offer much more detailed data from their products and spare parts, such as 3D pictures, product structures, and estimates about spare part delivery lead times.

Currently, Cimcorp does not have in-house capabilities to set up such a system, the reason lies in their ERP, yet the next version update will change for that. Thereby possible options are to wait for the next version update or purchase a special add-on to their ERP system that enables to operate web-portal. Technically the web-portal would be an e-commerce platform which then would be used only for information sharing with customers, but not to sell any goods, at least in this phase. Both options can be considered equally possible, and both can be roughly estimated as expensive to accomplish. In the end, the main question is how the project is resourced, setting up the web store with in-house resources requires much effort from the ERP team. While the next version update is for sure coming in the near future, one may ask if there are enough resources available for both projects.

Phase 3

In a third and final phase of the project, the vision is to achieve a state-of-the-art traceability system. One decision that was made during the project was that the plan must have a very loose temporal framework. What it means, is that each phase had to be planned (or re-planned) so that they could be executed separately, for example, one year separating the phases one and two. This decision was made hence there was a major change in the business environment (*Covid-19)*, which forced Cimcorp to postpone all non-critical development projects. The reason why this situation is brought up here is that it affects so radically the risk assessment of the project: for now, there is a legit risk that the third phase of the project will not be finished. Nevertheless, the plan for system development was done, despite the fact that it may not be finished.

As the vision of the third phase is clear and high-spirited, there still must be more concrete and tangible targets to be pursued for. The main targets are listed below:

- Investigate if customers are satisfied with the new QR based traceability system
- All product related data available at the web-portal
- After the traceability is implemented into all relevant departments, it should be developed together.

While the project reaches the final phase, it can be assumed that some kind of web-portal has been created and launched already. Since the web-portal is most likely operated on the e-commerce platform, there are great variety of opportunities such as own web store for spare parts of Cimcorp. During the third phase, the focus should be on the customer, how customer experience could be improved in the matter of traceability. The reason why customer experience is underlined with this web-store idea but was not discussed with the web-portal for traceability information, is that their nature is different: Cimcorp has the leverage to “force” the customers to use web-portal for data sharing, but not for web-store. And the reason for that is fairly simple, Cimcorp is in the monopoly situation with data, but most of the normal spare parts can also be purchased somewhere else. Surely the situation is as black-an-white as described above, but yet it underlines the fundamental difference of these stages.

If turns out that customers do not value the web purchasing option, it would be very useful to find out the reasons behind that, because it is possible that some or even majority of the customer still values the personal services (email and phone) too much for switching to use web-portal. In such situation the consideration would need to be done on how much further portal should be developed.

One step of this last phase is to implement QR codes and the whole improved traceability system into action at subsidiaries of the Cimcorp, which are located in India and Spain. Since both subsidiaries have just been founded a couple of years ago, they can be considered to be still in their founding state. This means that currently they do not even have the capabilities to adopt the traceability system into use hence they are still in the middle of the process of implementing the Cimcorp’s ERP system. But since the third phase of the project can be achieved at the earliest within a couple of years, so it is justifiable to expect that then the circumstances are more favourable for the implementation of the traceability system.

As have been mentioned earlier, the role of subsidiaries in the spare part operation at the Cimcorp is small, they offer locally all the services of Cimcorp, but they do not stock any spares on their site. Therefore, it can be said that their role is a bit different; they do not work directly with QR codes, all the parts that are shipped from the central warehouse to them already are labeled with QR codes. But hence they work on the customer interphase, they must know how to operate the system and how to promote it to customers. While working on the customer interphase it would be important to also collect some feedback from the customers continuously, which then can be time-to-time assessed globally.

By considering the customer experience and satisfaction it is a great way to summarize all three phases of the plan: the project was started since there was a clear need among the customer of Cimcorp to recognize broken parts easier and faster. As a solution for that, it was decided to improve the traceability of the spare parts. During the first phase, the most important matter was to create the solid foundations of traceability, which meant technology and subsystem implementations. During the second phase, there was still a need to focus on technological aspects, such as planning and creating web-portal for sharing traceability data. But already at this point it is important to get feedback from the customers, which also requires active measures of marketing.

5. CONCLUSIONS

As have been seen in this work, traceability at a theoretical level is a fairly simple concept, which however can become relatively complex in relatively fast when it is implemented into action. The reason for this challenge is diverse, leading to contingency theory one could say that there are as many reasons as there are cases. This chapter focuses on concluding the whole work, instead of discussing the single attributes of success, failure, or challenges of this project, the target is to paint a picture from single references or pieces of knowledge.

5.1 Key findings

The main targets of the work were to find an answer for two research questions: *what is traceability at the spare part business*, and *what techniques can be used to implement traceability to the case company*. In addition to presenting the key findings for these questions, there will be a brief discussion about the observations that were made during the planning process at the case company.

What is traceability at the spare part business – the answer to this question is twofold. In the field of traceability spare parts have not been studied that much, therefore the theoretical foundation of this study is based greatly on the studies of the food industry. Based on that theoretical framework it can be said that the basic concept of traceability can be adopted to spare part business with a grain of salt:

- The special features of a spare part supply chain set also some special requirements for spare part traceability.
- A comprehensive chain traceability system would benefit all the actors in the spare part supply chain, unfortunately, it rarely is possible
- The food industry has had a major contribution to defining the concept of traceability. Yet, there is no unambiguous definition for traceability.

The features that are typical to spare part supply chains, such as high volatility of the demand and long lifespan (or long stocking span) of the products, are the main reasons why there are things that need to be emphasised when discussing traceability of the spare parts. The long lifespan of the spare parts set some requirements for the traceability data, and especially to accessibility and availability. Therefore, it is also important to consider carefully how detailed traceability data is gathered. Demand peaks and high volatility overall is another thing that may affect traceability since traceability systems and processes must be upheld all the time, even if there would not be any transactions in a long time. However, it should be also underlined that the traceability system for spare parts is mostly very similar to other systems. They are all used for same reason, for sharing data between different actors, the special features of spare part management and spare part supply chains then affect on how that data is collected and utilized. Therefore, the features that are discussed here are not itself "special", they are just representative to spare part traceability systems.

The second research question was focusing on the technological aspect of the traceability: "What techniques can be used to implement traceability at the spare part business". Seven different techniques were introduced and compared together by using five criteria (*investment cost, operating cost, accessibility, suitability, and requirement for vast collaboration*) which were partly based on [56], and partly on the features that are characteristic to spare part business. As a result, three techniques were estimated to be well-suited for spare parts. However, the QR code was estimated to be the most suitable technique for Cimcorp hence it did not require large investments and it works well in harsh environments, and therefore it was recommended.

In addition to such findings that are presented above, there are couple of observations that were made during the implementation work planning at the case company: the role of a project manager is huge, especially in a process organization such as Cimcorp, and also that managerial decisions have a major effect for the outcome of the (implementation) team. It can be even said that both of the observations are linked to the challenge of managing the soft resources at projects. The role of management in traceability implementation projects, and in implementation projects overall were discussed in several sources [22, 40, 77, 78], and the observations that were made during the project are quite much in-line with them: in short, a project manager is key to success.

Based on the theoretical findings and described observations, the recommendations for the future for this project are listed below:

- Appoint a project manager: A project manager can coordinate and prioritize different requirements of different processes that are related to traceability
- Clear and solid schedule for each phase: this work provides the framework for the plan but takes no stand on the schedule.
- Improve the status of the project: currently, this traceability project is considered just as a matter of spare part department. If the traceability project, and its outcome, can be linked as a part of greater targets, it would be easier to forward.

5.2 Assessment of the study

Assessment of a study is an integral part of academic research, by assessing the outcome, conclusions, methods, and many other things, the researcher can authenticate the independency of the outcome and also itself. The assessment of qualitative and quantitative studies are done differently: the standard procedure in the field of qualitative research is to assess the study by using four criteria, which are listed below, while the assessment of quantitative research is based mainly on evaluating the collected material. [80]

- Creditability: How well the findings of the study (conclusions of the researcher) represent the reality.
- Transferability: How well the findings can be applied into the different context.
- Dependability: Is it possible to repeat the study and get the same results.
- Confirmability: Degree of the neutrality, all the conclusion must be based only to the presented materials and sources.

Creditability is usually considered as the most important criterion in the assessment of the qualitative research; hence it represents the relationship between the conclusions of the research (also research questions indirectly) and reality. In addition to assessing the conclusions, other things that can be assessed are interviews, scope of the source materials, and combination of different theories. Since the focus of this study was, in the light of research questions, theoretical, the question of creditability is highly dependent on the source materials, and conclusions that were made based on them.

Theoretical foundation of this work is formed from studies related to food sciences, hence spare parts and traceability is a topic that has not been studied together that much. The target was to form a general view of the traceability and then project it into the environment of spare part business. The fundamental challenge that lies in such logic is that it can be vulnerable: while the knowledge from the general level (about traceability) is scaled into a relatively limited field, i.e. to spare parts, the special characteristic of that field must be taken into account carefully. The challenge is also to recognize the main characteristics of the field that have been used as a baseline, which in this case was the food industry. To ease the described situation above, the fundamentals of the spare part management and spare part supply chains were introduced in the introduction chapter.

Another aspect of this work that can be assessed from the point of creditability, is the comparison of chosen technologies and techniques. Firstly, there was not any discussion about why those seven different technologies were chosen to be part of the comparison. The main reason for that can be found in the nature of this work, in a thesis work the scope is quite limited, so there are always some preferences that cannot be explained detailedly. However, all the chosen technologies have been successfully used in different traceability applications, so they are all equally plausible solutions. One target at the comparison was also to take along technologies that are used in different environments so that the optimal solution could be found.

The comparison itself is also a matter that can be discussed: how well the techniques can be assessed by using only academic sources, while they actual solution is highly dependent on the commercial application. This was a matter that was recognized, something that was considered when the features were chosen for the comparison. *Investment costs, operating costs, accessibility, suitability, and level of collaboration required* are all features that can be assessed from academic sources, and also by comparing them over each other.

Transferability another important feature, that needs to be assessed, it can discuss about the scope of the study, the environment of the study, and how well the results can be applied elsewhere. Since the topic is relatively well limited, there is a strong presumption that opportunities for applying the result into other fields are also limited. The major problem with this study that is related to transferability is the lack of empiricism. As have been mentioned, there was a plan to run a pilot test, and report it at this work, but unfortunately, it could not be executed as was planned. In this case, the circumstances are what they are (Covid-19 had a major effect on the schedule), they cannot be affected. From the point of transferability that is challenging: the reader should be able to assess if the result can be applied into other field, but currently there is no hard evidence that it can be even applied into this field.

While considering the dependability of the study, the thing that should be assessed is how well the study and its processes are described, is it possible to renew the study, with the material that is presented at the study, and end up in the similar conclusion. The founders of this assessment framework, Lincoln and Guba, have stated that usually there is a strong correlation between creditability and dependability. If both research questions are assessed separately; conclusion for the first research question more dependable than conclusion for the second one. The reason for that is lies in the challenge that is already described – comparison of technical solutions is hard, since they are so much dependent on commercial solutions.

The last feature on the assessment framework of Lincoln and Guba is confirmability, which focuses on assessing the neutrality of the results. While considering the first research question and how it is handled at this work, is can be assessed that there is no any prejudices, the question itself does not limit the possible results, and the conclusion is based on the presented material. The second research question, again, is bit more challenging: hence there is no description about how presented seven technologies were chosen into this study, one may consider that it affects on the confirmability. Another thing that may be considered from the point of confirmability is the comparison itself, did it really consider each solution as equally possible - the answer is yes and no. No. since there was a clear target to find the best solution for the selected environment (Cimcorp). Yet, each technique was equally assessed within that framework, and the proposal that were given to Cimcorp was fully based on the presented criteria, which were presented at the beginning of the chapter 3.

5.3 Further research

While considering the future of the spare part traceability there are couple of things that can be thought as self-evident: increased interest to blockchain technology and traceability in general level. The big question with blockchain is *how blockchain technology can be utilized to spare part business to increase traceability*, already it can be known for a sure that blockchain technology has great potential to enhance many business processes. A great example of the hype that is related to blockchain is that during this study several studies were published which are discussing the blockchain technology and its applications, one rather interesting was "*Blockchain-Based Solution for the Traceability of Spare Parts in Manufacturing"* [81]. Similar studies can be expected in the future more, which can be considered to be beneficial for the field of spare part management and traceability.

From a technological point of view, IoT is another technology that most definitely should be studied more. In light of the sources that are presented at this work it can be assessed that IoT could be used to improve traceability in the system level, such as in assemblies or in production systems. As can be know, the field of IoT studies are very wide, but still there are not too many studies discussing IoT from the spare parts point of view.

In addition to matter that are discussed above, there also more theoretical questions that should be studied and discussed in the future, such as: *what are the special characteristics of the spare part traceability or are there any, could traceability data be used to improve demand forecasting of the spare parts* and *does product traceability increase the customer value in the manufacturing business.*

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